

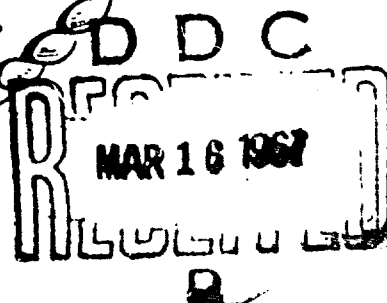
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A REFERENCE GUIDE FOR THE CONSTRUCTION AND INSPECTION OF WOOD PALLETS

Project No. NT003-020



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A REFERENCE GUIDE FOR THE CONSTRUCTION AND
INSPECTION OF WOOD PALLETS

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**U. S. NAVAL SUPPLY RESEARCH AND DEVELOPMENT FACILITY
BAYONNE, N. J.**

**A REFERENCE GUIDE FOR THE CONSTRUCTION
AND INSPECTION OF WOOD PALLETS**

**Project NT003-020(p)
Sub Project SE52-76
Engineering Report No. 2.4182
15 July 1954**

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ABSTRACT

→ 7. This reference handbook is intended for use by government pallet inspectors and commercial pallet suppliers, in order that suitable pallets will be accepted in the Navy Supply System with minimum cost possibilities. It contains factual pallet data, descriptions of usage, and inspection guides for pallet lumber.

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A REFERENCE GUIDE FOR THE CONSTRUCTION AND INSPECTION OF WOOD PALLETS

INTRODUCTION

The U. S. Armed Services are the largest single users of wood pallets in the entire world. Latest available figures placed some 60 million wood pallets in use by the Armed Services. In addition, military procurement of pallets for the fiscal year 1952 amounted to 2,633,797. Approximately 45% of this total was purchased to satisfy Navy Department demands. It is readily apparent why specifications for wood pallets are of major concern. Current specifications for wood pallets have been prepared after considerable test and development work. Investigations were made into the most minute pallet details relative to the basic operational requirements of the Armed Services. The objective was to secure an effective pallet specification which would permit delivery of commercially manufactured wood pallets, acceptable for the intended use, at the least possible cost. However, a carefully written specification is only as effective as the care exercised by pallet manufacturers and inspectors in complying with and correctly interpreting its provisions.

During the past several years, a general lack of understanding was noticed on the part of pallet manufacturers in their interpretation of certain portions of pallet specifications. In addition, it was found that different standards of inspection prevailed among the regional offices of the Inspector of Naval Material. The result was that certain shipments of pallets being received were of such poor grade that the useful life of the pallet could be only a small fraction of the normal life expectancy.

In view of the large quantity of pallets used by, and procured for the Armed Services, the acceptance of inferior pallets is uneconomical in that large maintenance and repair costs may be anticipated. Inferior pallets also present a considerable safety hazard.

In the past, attempts have been made to apprise pallet manufacturers and inspectors of the seriousness of the situation. As early as 1949, the Supply Engineering Division of the U. S. Naval Supply Research and Development Facility, presented to the mem-

bers of the National Wood Pallet Manufacturers Association, a demonstration of actual operating conditions encountered with pallets in the Navy Supply System in conjunction with a thorough analysis of pallet details. This afforded the pallet suppliers an opportunity to see first hand the reasons why Navy Pallet Specifications must be based upon a realistic appraisal of each characteristic of its use.

Continuing along this line, the Bureau of Supplies and Accounts, by letter dated 5 November 1951, authorized the Supply Engineering Division, U. S. Naval Supply Research and Development Facility to conduct an investigation into inspection procedures for wood pallets. The objective was to develop a system wherein standardization and uniform methods of pallet inspection might be effected.

This reference guide for wood pallets is the direct result of the investigations conducted. It is believed that the material contained herein will assist the pallet suppliers and inspectors by providing pertinent background data and fundamental principles necessary for the exercise of proper judgment in making decisions relative to the manufacture and inspection of wood pallets. In addition, such material can well be a basis for the indoctrination of inexperienced industrial and government personnel, both civil and military.

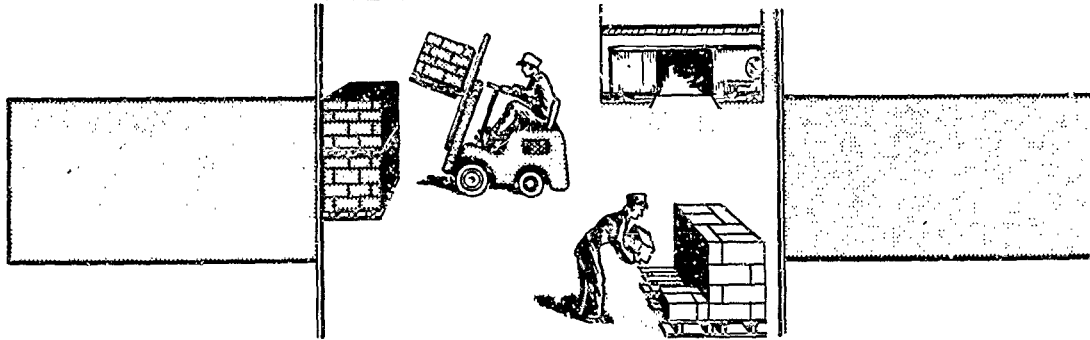
Six distinct sections are presented: sections I and II deal with the operational and practical background of pallet usage and handling equipment; and sections III to VI inclusive, present fundamental information about pallet lumber upon which grading and inspection rules are based. The latter sections were prepared by the Forest Products Laboratory, the leading authority on lumber in this country.

An index is appended to afford a ready and handy system of locating desired information.

Pallet manufacturers and government inspectors should bear in mind that the material presented in this book should in no way be interpreted as superseding any requirement in the contract specifications. However, this book will serve as a handy guide towards the end purpose; a well constructed, serviceable pallet, suitable for military requirements, at the least possible cost.

SECTION I

PALLET DEFINITIONS



1.1 GENERAL. A pallet is a portable platform on which merchandise is placed to facilitate transport and materials handling; a two deck structure which permits mechanical handling and tiering of unit loads of materials or products; and a modern version of the old time industrial skid, different in that it conserves cube and permits handling and tiering of unit loads by high lift mechanical equipment.

Among the advantages gained by use of the pallet are:

- (a) Speed in handling
- (b) Utilization of overhead storage space
- (c) Use of inexperienced labor
- (d) Reduces re-handling costs
- (e) Lessens damage and pilferage
- (f) Reduced terminal time
- (g) Improved ventilation in storing perishables
- (h) Simplification of vermin control

(i) Reduction of industrial accidents

(j) Rapid movement

1.2 TYPES. There are basically three different headings into which pallets may be classified: (a) expendable, (b) general purpose, and (c) permanent pallet. The material used for construction, cost, and the intended usage, usually are the factors which determine the category into which they may be placed.

1.3 NAILED WOOD PALLET. The type predominantly in use by the Armed Services is the general purpose nailed wood pallet. This type is one with which this book is principally concerned. The selection of this material type for general use by the military is due to its versatility, utility, cost, availability of material, simplicity of design, strength characteristics and ease of repair. When properly constructed, this pallet is known to give long time service at a minimum of repair cost.

For purposes of clarification, the two other basic types are briefly described as follows:

1.4 EXPENDABLE PALLET - a low cost, lightweight, special purpose pallet requiring different design considerations for each individual application. Normally used as a shipping medium for unit loads to effect maximum savings in shipping costs.

1.5 PERMANENT PALLET - a heavy duty pallet usually constructed of metal or wood or a combination of both and used primarily for intra- and inter-plant storing and handling of heavy raw materials or bulky merchandise principally used in industrial plants.

1.6 DESIGNS. There are many variations of the general purpose nailed wood pallet. The designs more commonly utilized are described below. Each design contains the features of construction found to provide the most efficient results in the particular application for which it is intended.

1.7 FLUSH-STRINGER TYPE - a pallet in which the deck boards are flush with the outside faces of the between deck supports.

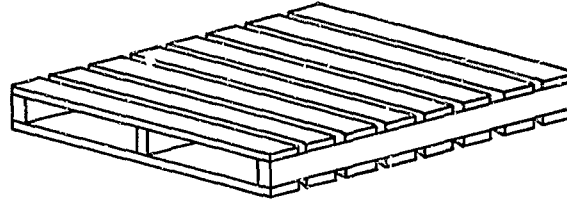


Fig. 1. - Flush type-reversible-2 way entry

This design usually has a two way entry for fork lift equipment and top and bottom deck construction is similar. This reversibility of decks provides more bottom area support for proper distribution of the load under tier.

1.8 DOUBLE WING TWO WAY ENTRY - this design is a standard type used by the Navy during World War II. Bottom deck openings are provided to enable handling by hand operated pallet trucks.

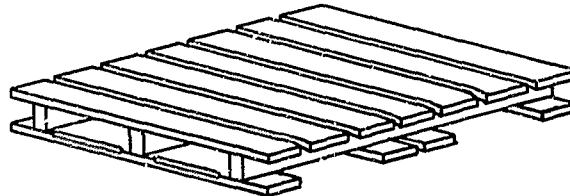


Fig. 2. - Double wing type-non reversible 2 way entry

The stringer supports are set in from the edges of the deck boards to accommodate bar slings when hoisting pallet loads in shiploading operation. The common size is 48" x 48" which is ideally suited for railroad car dimensions and warehouse layouts. This size permits efficient stacking of the majority of commercial package sizes.

1.9 DOUBLE WING-FOUR WAY ENTRY - the between deck supports consist of individual posts which enable entry of all mechanical handling equipment on all four sides of the pallet. This design was adopted by the Navy shortly after World War II. The four way feature of this type, together with an overall

pallet dimension of 40" x 48", meets the requirements imposed by both railroad car and truck dimensions and permits efficient use of available space in either of these two methods of transportation.

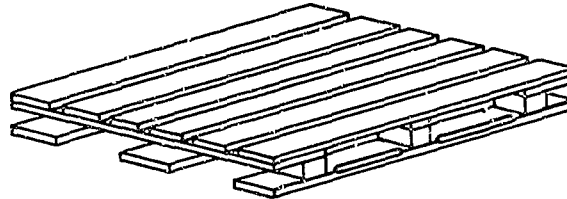
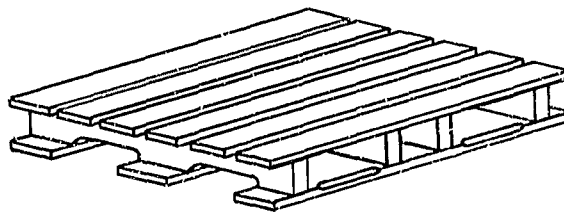


Fig. 3. - Double wing type-non reversible 4 way entry (posts)

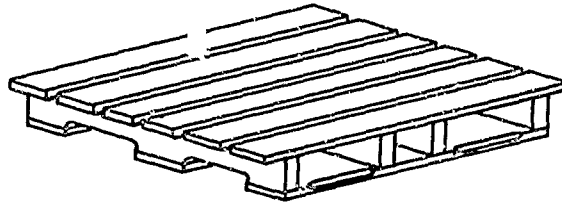
Posts are spaced inward from the edges of the top deck to provide wings for hoisting by slings. The bottom deck boards are spaced to allow the wheels of the hand operated pallet trucks to drop through.

1.10 DOUBLE WING - NOTCHED - Stringer - this design is similar to the Double Wing Two Way Entry pallet. The difference is that two cutouts are made in each stringer length to allow entry for the forks of the high lift trucks. This design permits a four way entry for fork trucks but only two way entry for hand pallet trucks.



**Fig. 4. - Double wing type-non reversible
notched stringer -4 way entry (partial)**

1.11 SINGLE WING - NOTCHED STRINGER - a pallet in which the stringers are set in from the ends of the top deck boards only. The bottom deck boards are flush with the faces of the stringer.



**Fig. 5. - Single wing type-non reversible
notched stringer 4 way entry (partial)**

Each stringer has two cutouts for entry by high lift fork trucks. This design allows four way entry by fork trucks and two way entry by hand operated pallet trucks. The purpose of the single wing is to allow use of straddle type manually or mechanically operated lift equipment where conservation of aisle space is required.

1.12 STEVEDORING (CARGO) PALLET - the inclusion of this size (48" x 72") pallet as a general purpose type is justified because of its extensive use by the Armed Services in terminal, shiploading and warehousing operations.

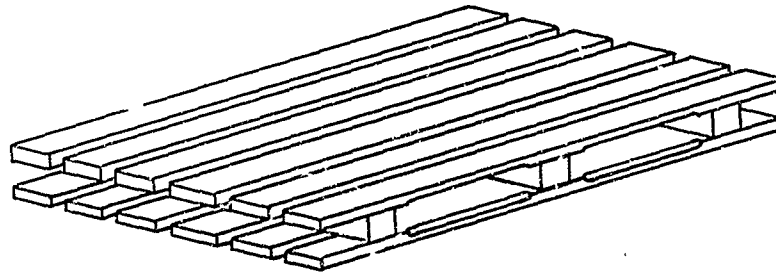


Fig. 6. - Cargo pallet (stevedoring) 48" x 72"

This structure is usually composed of nominal 2" x 8" lumber with top and bottom decks alike.

The stringers are nominal 4" x 4" set in from the ends of the deck boards to allow for insertion of the sling bar under the top deck boards. Two way entry for high lift fork equipment is provided. The principal application of this pallet is in the handling or storing of large, irregular or heavy loads.

1.13 INTENDED USAGE. The general purpose nailed wood pallet has multiple military application. In conjunction with the conventional types of fork trucks it is employed as a means for handling, shipping and storing of a considerable number of different items (See Figures 7 to 10). Its advantages have already been stated in paragraph 1. The operational requirements of a pallet may include service anywhere from a continental military supply establishment to a supply dump located on a remote overseas island.

1.14 HANDLING EQUIPMENT. The equipment used to handle the loaded pallet will include many types. The standard types are the high lift fork truck and the manually operated low lift truck. There are many different designs and sizes of these two basic types, the selection usually is dependent on the characteristics demanded by the particular storing and shipping operation or by local conditions (See Figures 8 to 14). Other equipment used to handle pallets will include types peculiar only to the military. Figures 15 to 22 depict the actual procedures followed in handling loaded pallets in operations wherein conventional methods cannot be utilized. These illustrations will indicate the details that have been carefully incorporated into the pallet design and specification to insure suitability for the intended military functions.



Fig. 7. - Typical Navy warehouse showing variety of different shaped items handled on wood pallets in the military supply system. Neg. No. 294-3.

Fig. 8. - Typical warehouse tiering operation. Note utilization of height space by fork truck pallet system. Sound pallet construction is required to insure safety of operation. Neg. No. RS-41-5.



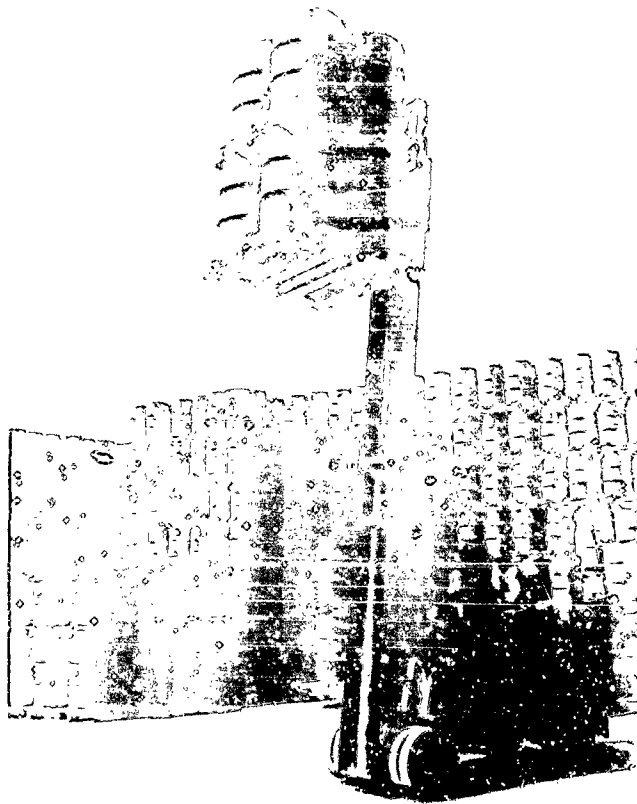
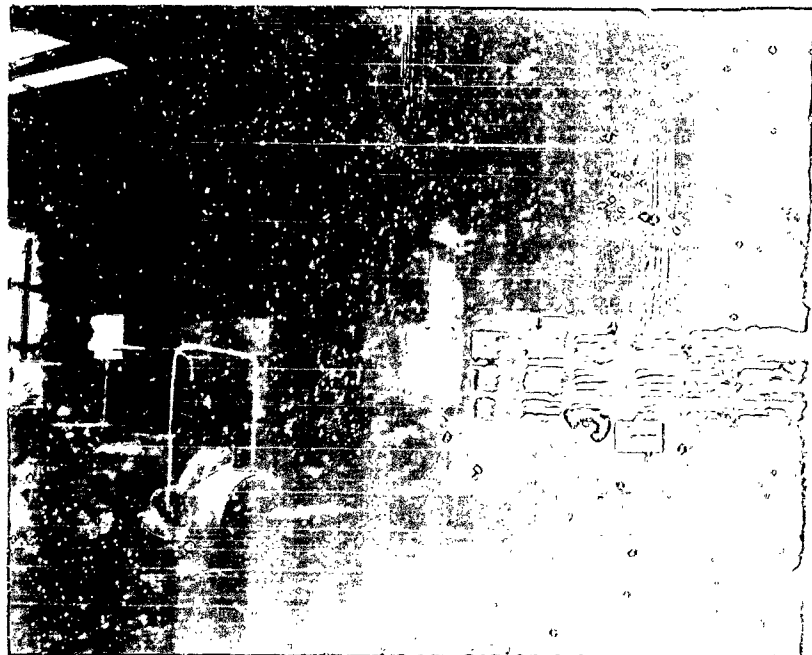


Fig. 9. - Outdoor storage operation. Wood pallet provides speed of handling, efficiency, and safety of operation in high stacking. Neg. No. 316-1.

Fig. 10. - Tractor-trailer combination used to convey palletized unit loads over long distances within a military supply depot. Fork truck is unloading dollies in the warehouse and tiering the loads. Neg. No. 154-1.



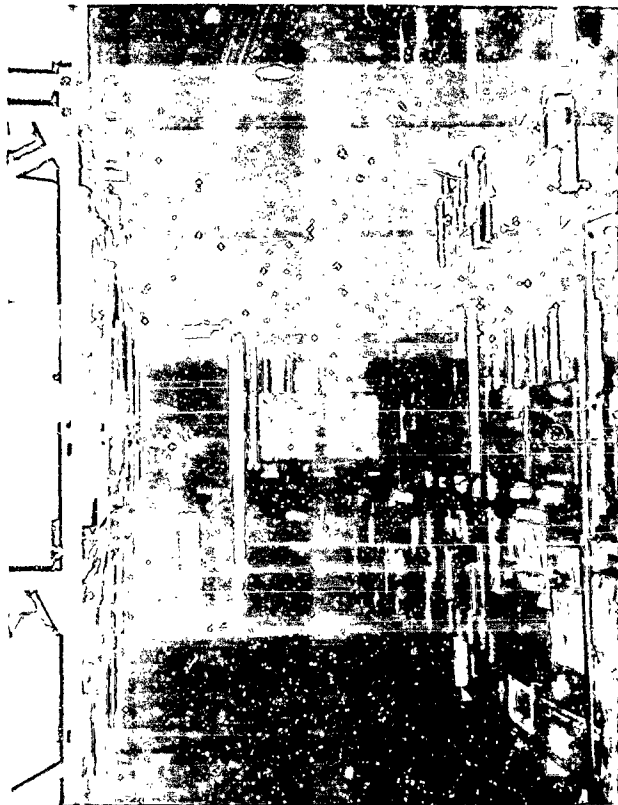


Fig. 11. - Straddle type fork truck and pallet rack operation. Single wing wood pallets are employed so that straddle arms may enter under the pallet on the ground to work close to the rack tier. Neg. No. 139-1.

Fig. 12. - Loading of a freight car with palletized loads. Wood pallets must be able to resist the impacts encountered in freight dumping operations and be able to protect the lading during such shipment. Neg. No. 249-1.



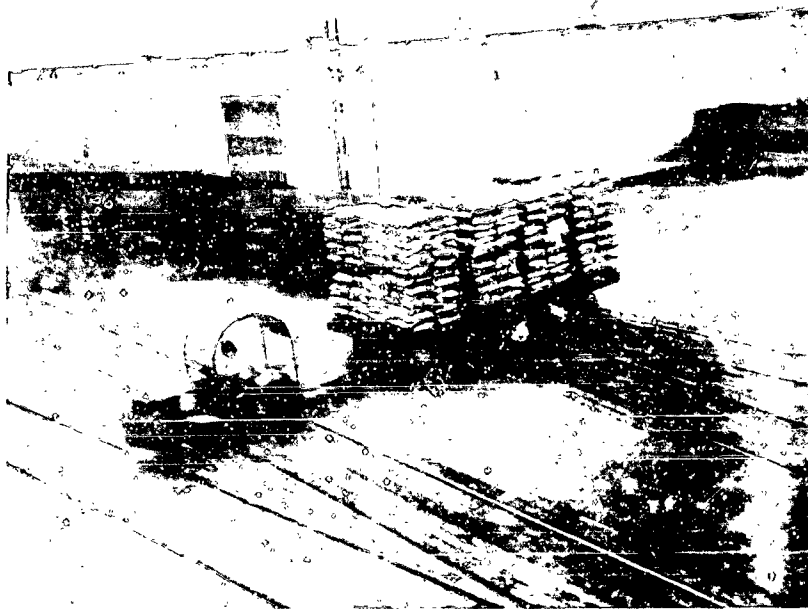


Fig. 13. - A tractor-flat combination moving pallet loads to the transshipment shed at a Navy Supply Depot. Neg. No. 267-3.

Fig. 14. - Method used to position first load in freight car unloading. Fork truck is then placed in car for handling remaining loads. Dragging of pallet requires strong material construction. Neg. No. 297-4.

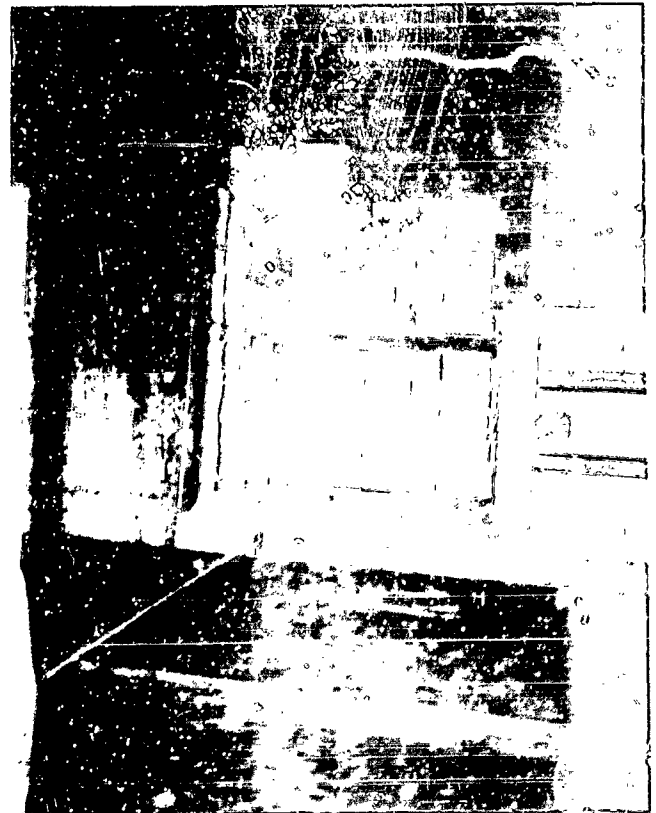
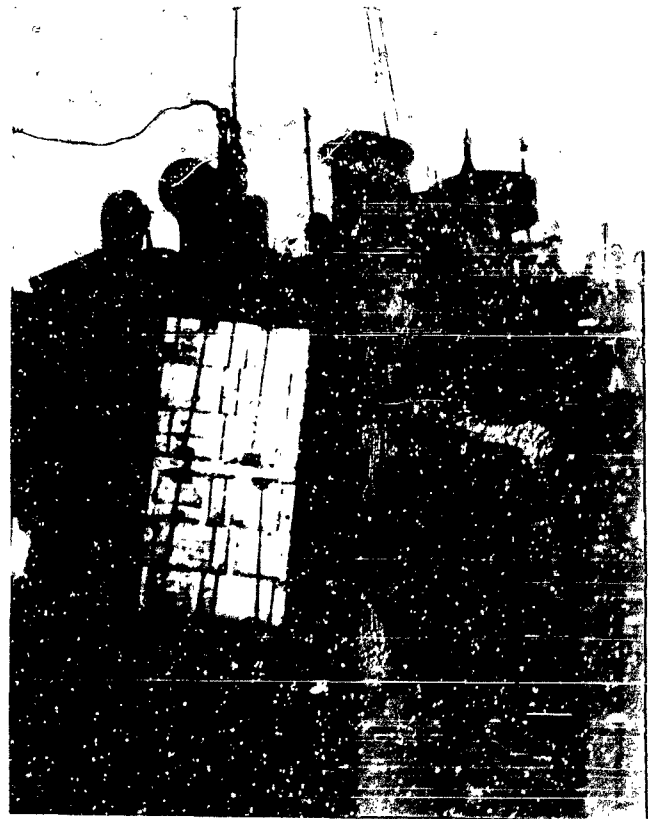




Fig. 15. - Typical stevedoring operations. Note variety of equipment needed to handle pallet loads. Pallet is subjected to considerable abuse during these operations and requires strong design to resist damaging forces. Neg. No. 287-6.

Fig. 16. - Typical slinging operations for shiploading of pallet loads. Rugged pallet construction is required to absorb impacts during hoisting and dropping of loads. Neg. No. 62-19.



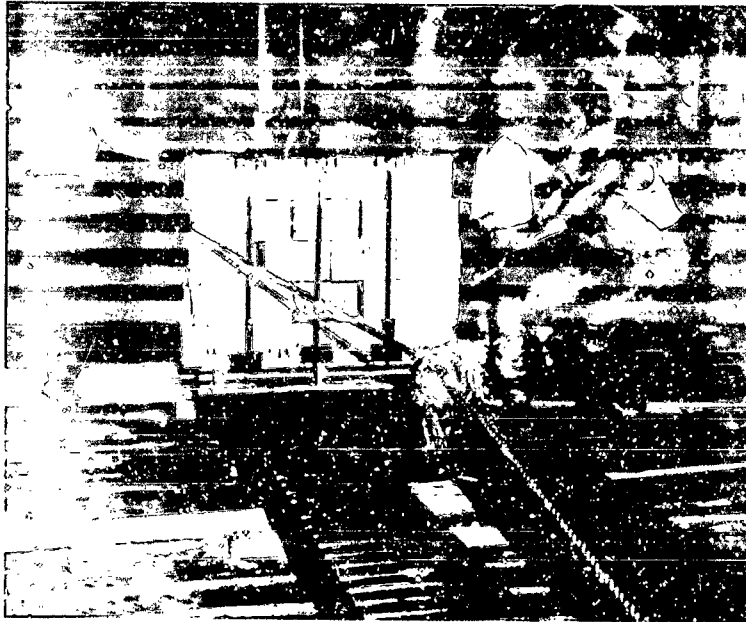


Fig. 17. - Movement of pallet load over sections of roller conveyors during stevedoring operations. Wood pallets must be able to withstand the concentrated forces indicated in photo. Neg. No. 317-4.

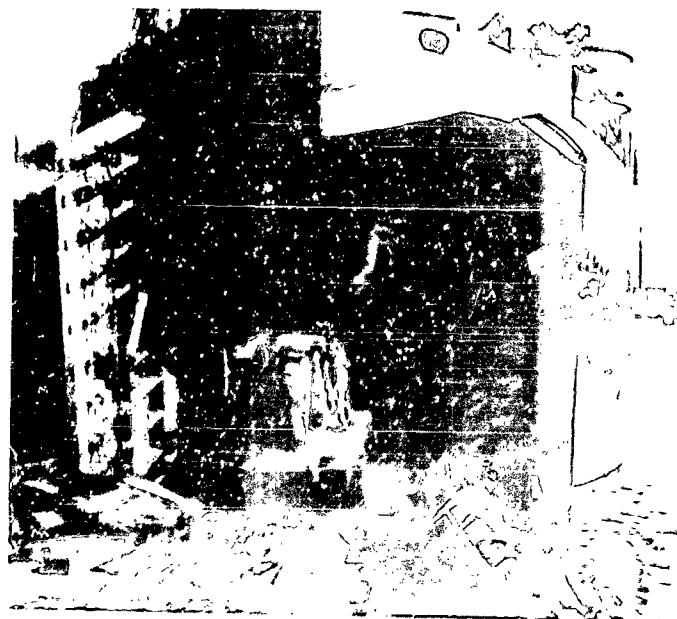
Fig. 18. - Fork truck pallet operation in the hold of a ship. The pallet must have general duty capability for overseas requirements. Neg. No. 287-5.





Fig. 19. - Typical handling of palletized loads in amphibious operations. Crawler type fork truck is used to move pallet loads over sandy beaches. Neg. No. 298.

Fig. 20. - Typical military operation showing pallet loading of a landing ship. Pallet handling is severe in such operations and requires a strong pallet design. Neg. No. 317-6.



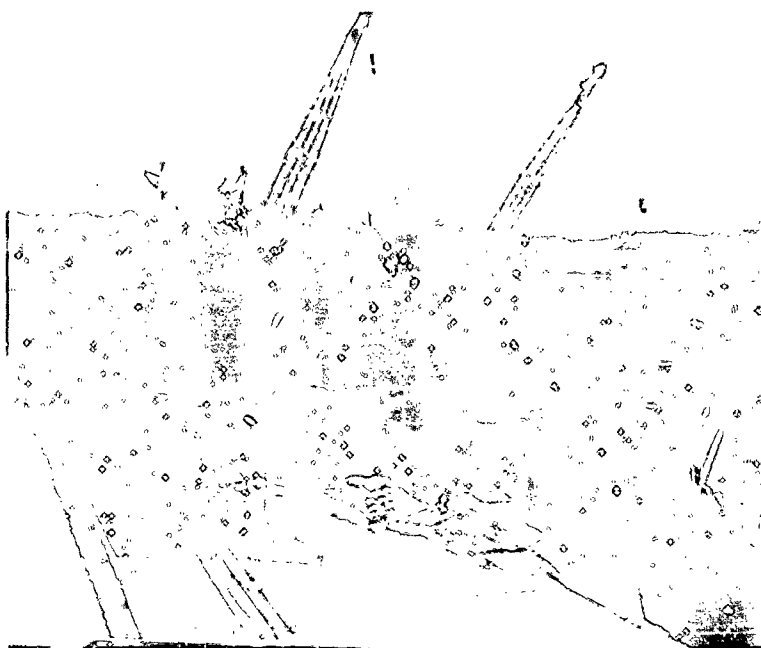


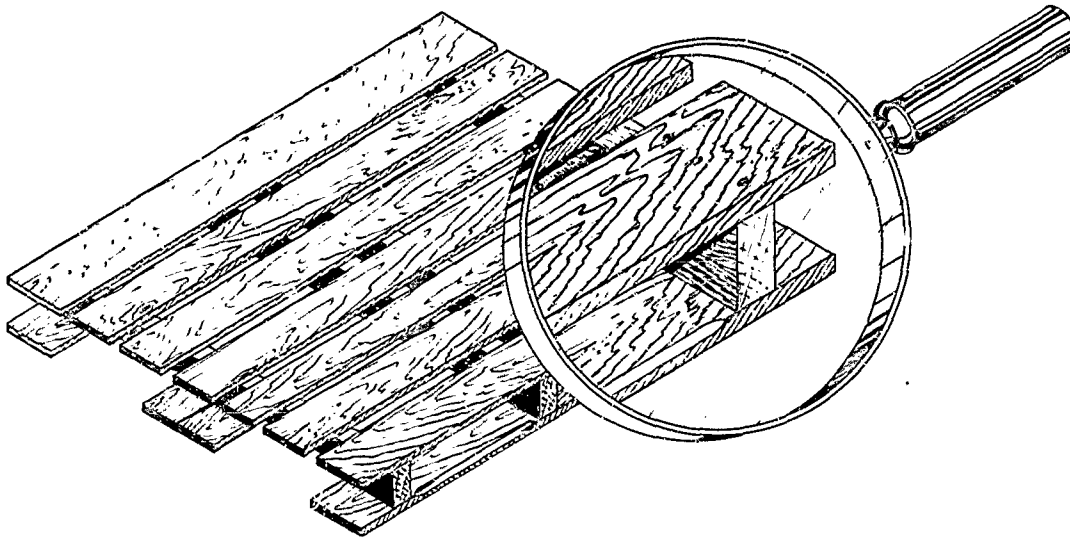
Fig. 21. - Typical overseas port operation. Pallet usage in such operations indicates the wide area of pallet requirements for the military services. Neg. No. 317-3.

Fig. 22. - Method used to move pallet loads in emergency operations when lift equipment is not available. Pallet toboggan towing is used in amphibious operations. Neg. No. 245-6.

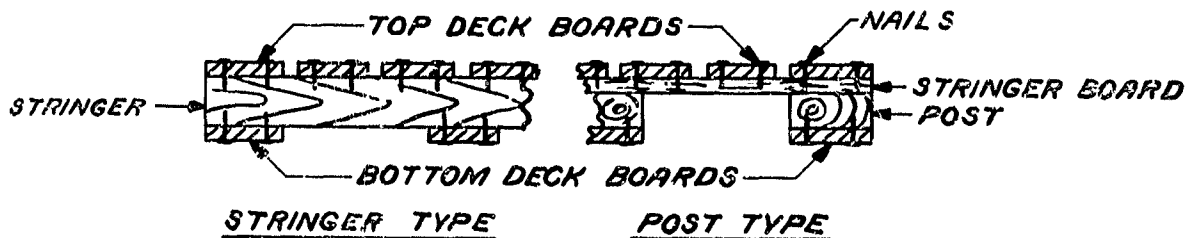


SECTION II

PALLET REQUIREMENTS



2.1 COMPONENT PARTS. The general purpose wood pallet contains either all or a majority of the following sections: (a) load bearing surface or top deck, (b) vertical support members and, (c) bottom deck or floor bearing surface. Both hardwood and softwood are used in manufacture in accordance with particular specifications. The parts are bonded together by the grooved shank pallet nails which provide an efficient and strong pallet structure at the least cost. The accepted nomenclature used by military specification for the pallet parts is illustrated in Fig. 23. These parts will be covered in detail further in this report.



WOOD PALLET PARTS

Fig. 23. - Pallet Nomenclature

2.2 WOOD. By far the most widely used material for military pallets is hardwood. Considerable research and development work, together with long time usage data, has firmly established this material as best for overall military requirements at minimum cost. Hardwood pallets, properly constructed, have been known to have a life span of over ten years with low maintenance costs in the military supply systems. (Fig. 24). However, this advantage can be quickly lost when the material and workmanship employed in pallet construction is of low grade. People having an interest in pallet procurement should be aware of the expected hard usage a pallet encounters in the Armed Services. Unlike a commercial plant in which the pallet usually serves a specific function, the military has a considerable amount of different applications, thousands of different items to be handled and overseas and emergency conditions to be considered in the overall pallet usage requirements. The hardwood pallet has been found to provide the most economical results for general purpose duty covering all the above conditions, both in original cost and in maintenance requirements.



Fig. 24. - A properly constructed hardwood pallet can be expected to have a long and efficient life with minimum maintenance costs. This pallet is estimated to be at least 10 years old and is still useful. Neg. No. 151-13.

For special cases when or where the availability of hardwood for pallets may be limited, specifications for a general purpose pallet having softwood parts have been prepared. However, the inclusion of softwood in the pallet structure has been made at points that do not generally receive hard wear and are not exposed to damaging conditions. It has been determined from performance data that the parts of the pallet that are more susceptible to damages in abnormal operations are the outer end boards of the decks and the vertical support members. Military specifications covering softwood pallets will usually include hardwood at these points. When a more liberal use is made of softwood for pallets, the members are of greater

thickness so as to be comparable to hardwood in strength and wearing qualities. The stevedoring (cargo) pallet composed of nominal 2" softwood deck boards and nominal 4" x 4" softwood stringers is an example of softwood usage that has given satisfactory performance. (Fig. 25).



Fig. 25. - Efficient use of softwood for pallets is made in the stevedoring (48" x 72") cargo pallet shown at left. Relative strength qualities comparable to the 40" x 48" hardwood pallet at right is obtained by increased lumber thickness. Neg. No. 151-15.

The hardwood species utilized for pallet construction include those found in GROUP 4 woods. This group contains those woods having the greatest nail holding power and the highest resistance to wear. Another important characteristic found in these woods from a pallet standpoint is their cleavage values which indicate the resistance of the wood to chip and split. This quality is particularly important for the post members of the pallet which are continually exposed to impacts from the forks of lift equipment when they are entered between the pallet decks. (Fig. 26). Tests conducted by the

Forest Products Laboratory have indicated that the cleavage values give a good indication of the expected behavior of a species of wood under impacts from the forks. Thus, when species with high cleavage values (such as those found in hardwoods) are used for post and stringers, the pallets may be expected to afford more resistance to splitting and chipping than constructed from species with low cleavage values, such as those found in softwoods. Specifications covering softwoods for pallets have been carefully prepared to include only those softwoods having the better overall strength characteristics. In collaboration with the U. S. Naval Supply Research and Development Facility, the Forest Products Laboratory has conducted considerable studies and tests with different softwood species and has advised on the selection of those species having the better advantages for pallet use. These species are usually found in the GROUP 1 and 2 woods. It is mentioned again, however, that when softwood is used for pallets it must have strength equivalent to hardwood. This is made possible by increased thickness.



Fig. 26. - Effect of using woods for posts having low cleavage values such as those found in softwoods. Note chipping and splitting of posts due to sharp impacts. Neg. No. 557-4.

2.3 MOISTURE CONTENT. The most important condition that directly affects the serviceability and life of the wood pallet from the date of purchase is the moisture content of the lumber used in manufacture. Pallets constructed with seasoned lumber will contain the following important qualities that are definite factors governing performance and life expectancy of the pallet in service:

- (a) Greater strength

- (b) Longer life
- (c) Better nail holding
- (d) Resistance to decay
- (e) Minimal shrinkage
- (f) Dimensional stability
- (g) Overall economy

The results of tests and long time service data have clearly shown that a pallet constructed with wood having low moisture content will give long time service use with minimum repair costs. Military pallet specifications generally list the moisture content requirements in the form of average percent moisture contents for the component wood parts, and place a limit on the maximum amount of any one member. This allows a practical method of obtaining pallets with an acceptable moisture content and yet is considered not too restrictive. In spite of this, the moisture content requirements of military specifications has been the object of much controversy with regard to compliance and inspection. Much of this has been attributed to the fact that most pallet suppliers have treated this requirement lightly at the time of bidding on government pallet contracts. Another factor has been limited availability of seasoned wood for pallets due to lack of time, space and means to season lumber properly in the majority of pallet manufacturing mills. Most of the difficulties have been resolved by specifying different grades of wood pallets based on the moisture content requirement. In this way, when the availability of seasoned wood may be limited for pallets, suppliers would have the opportunity to submit bids on a grade of pallet having high moisture content. While this is considered detrimental (see Fig. 27 and 28), in that inferior grades of pallets will be accepted into the supply system, it has maintained large scale competitive pallet bidding for government procurements which is beneficial from an overall military standpoint in times of emergencies.



Fig. 27. - Result of use of high moisture lumber in pallet construction. Stringer board has warped and is in a position to be damaged. Neg. No. RS-151-7.

Fig. 28. - Exposed nail heads in pallet top deck have caused damage to bagged material. The cause may be traced to high moisture content of lumber at time of pallet manufacture and subsequent drying and shrinkage of the board. Neg. No. 151-5.



2.4 QUALITY OF LUMBER. It is obvious that the structural strength and life span of a wood pallet would depend to a very large extent on the quality of lumber used in its construction. The different grades of commercial lumber are distinguished by the amount and size of defects permitted in a piece. The Forest Products Laboratory defines "defects" in lumber as, "any irregularities occurring in or on wood that may lower some of the strength, durability or utility value". The military pallet specification has treated this important requirement only as it directly affects the performance of the pallet for its intended use. Limitations on the size and amount of defects have been incorporated in the specifications to insure a pallet suited for its requirements and yet permit utilization of grades of lumber in which maximum economies are made. The characteristics of lumber defects influencing pallet design are covered in complete detail by the Forest Products Laboratory in Section VI of this report. An attempt is made here to emphasize the results that can be expected when the limitations on imperfections of lumber are disregarded. Figs. 29 and 30 are illustrations of the actual condition of pallets received at a military installation and indicate a complete failure to comply with pallet specifications. A further discussion on the effects such inferior grade lumber may have on pallet performance based on the individual component pallet parts follows.

2.5 BOARDS: The greater percentage of parts built into a wood pallet structure are boards. These members form the surface areas of the top and bottom deck and as such are subjected to severe impact. This is a normal condition in pallet handling operations and results from any of the following actions: dropping of packages on the deck, stevedoring operation in which the loaded pallet is hoisted by bar slings and lowered and then stopped abruptly, dropping and positioning of empty pallets by laborers, and striking of the pallet boards by mechanical lift equipment. It can be seen that any defect in board lumber affecting the strength of the piece would result in repeated repairs and high maintenance costs. The stipulations in pallet specifications with regard to quality of pallet board lumber have been based on a realistic approach, namely, that the wood need not be of high and costly quality, but that the limitations placed on the nature and size of defects would permit economies in procurements without sacrificing economy in pallet operations.

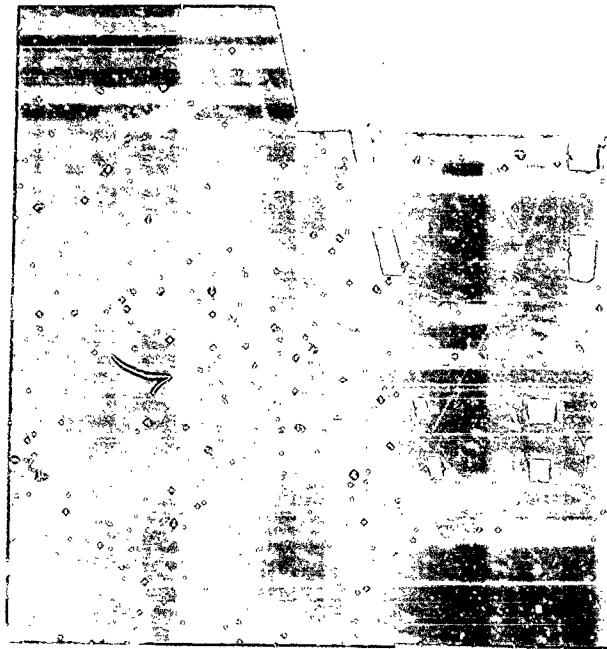


Fig. 29. - Actual condition of new pallets received showing non-conformance to the specifications. Use of boards having excessive wane results in false economies. An early trip to the repair shop is likely, thus increasing maintenance costs. Neg. No. 600-8.

Fig. 30. - Utilization of lumber having only scrap value indicates a total disregard of the specifications by the manufacturer. Large decays will render the post useless for nailing and unsafe for operational work. Excessive costs are involved to replace a post. Neg. No. 600-3.



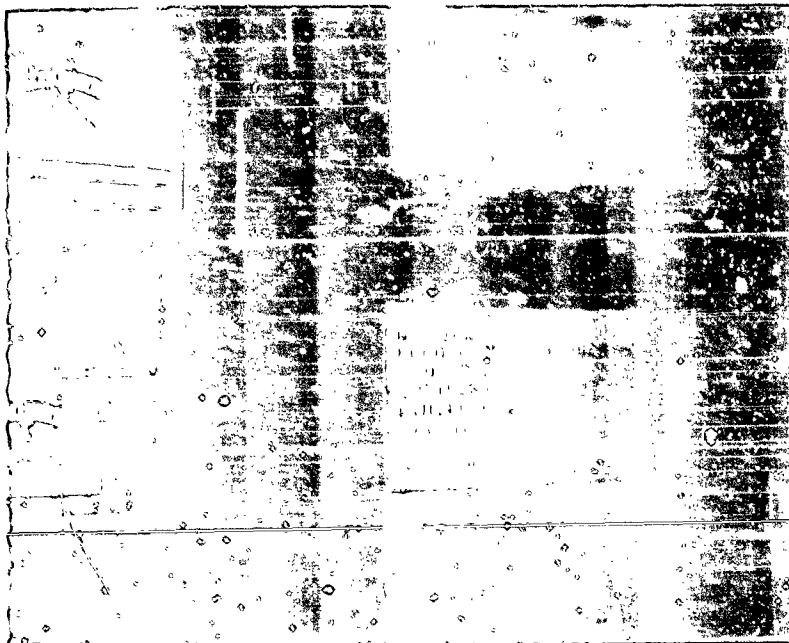


Fig. 31. - Typical of damages to the pallet end boards due to rough handling. Note how the stringer board may have better resisted the impact if it had been properly nailed at the time of manufacture. Neg. No. 151-14.

Fig. 32. - Illustrating defective lumber used in pallets that have actually been received. The excessive knot hole in the stringer board has earmarked this pallet for an early visit to the repair shop or possibly the scrap heap. Neg. No. 151-11.





Fig. 33. - Illustration of an unsound knot and cupped deckboard on a typical pallet rejected by a government inspector. Neg. No. 321-1.

Fig. 34. - View of improperly nailed pallet. Note that top deckboards are not flush with stringers. Gap between board and stringer is due to nails not being fully driven. Upon use, pressure of load would force board down against stringer but nails would project and would tear bagged goods and cause other damage to palletized loads. Sloppy workmanship on pallets such as this should be rejected. Neg. No. 321-2.



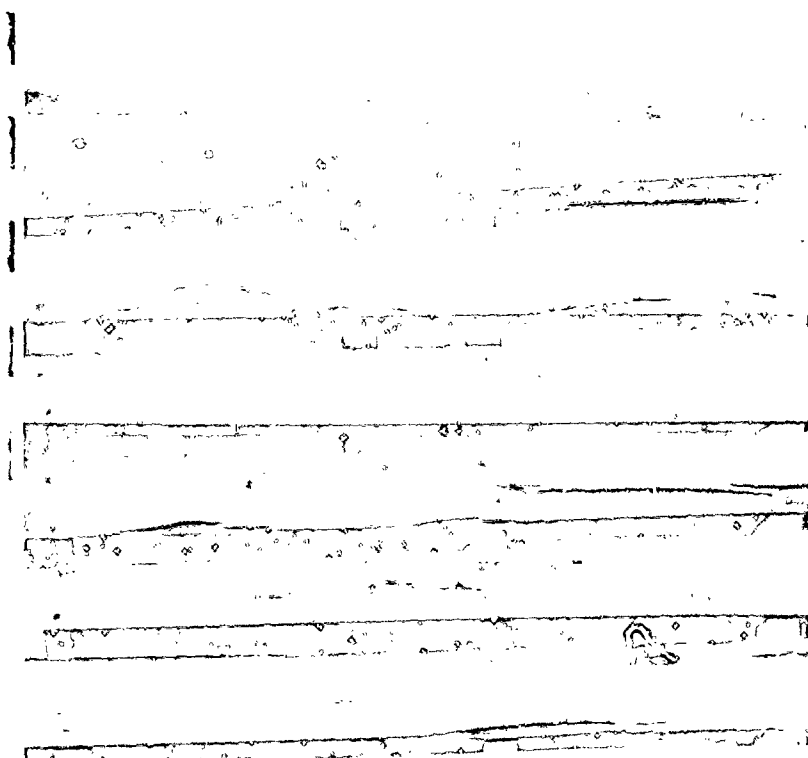


Fig. 35. - Another illustration of poor pallet assembly and material. Pallet is out of square since stringers and deckboards are misaligned. Lower stringer has excessive split. Pallets such as these should be rejected since maintenance costs on such pallets are excessive. Neg. No. 321-3.

Fig. 36. - Illustration of pallet rejected by a military inspector due to multiple reasons:

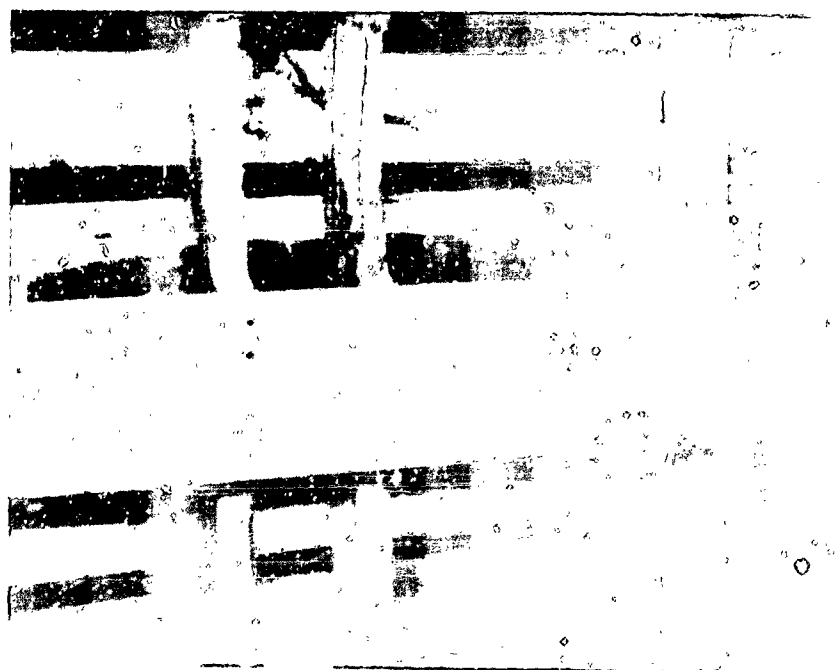
Item 1. - Rotten stringer.

Item 2. - Excessive splits in stringer.

Item 3. - Excessive small worm holes and decay.

Item 4. - Unsound Knot.

Neg. No. 321-4.



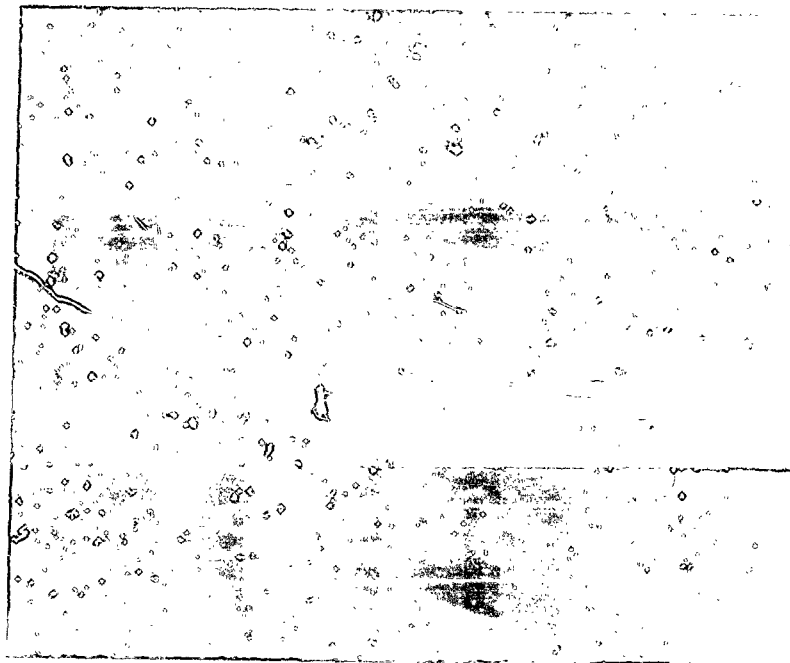


Fig. 37. - Illustration of poor nailing practices as applied to pallets. Bent and protruding nail heads on pallets can easily cause excessive damage to commodities carried thereon, particularly bagged goods. Drive screws used on dry lumber pallets seldom loosen and project when once properly driven. Also shown is a twisted stringer resulting from nailing too close to edge of stringer. Neg. No. 321-5.

Fig. 38. - Illustration of poor lumber for pallets. Hardwood specimens of not acceptable deckboards.

No. 1. - Decay - bleached areas reveal decay in which the disintegration is readily recognized because of the soft and spongy bleached areas - not acceptable.

No. 2. - Decay - pronounced longitudinal strip of decayed area readily recognized because of the soft and spongy bleached area - not acceptable. Neg. No. 321-6.

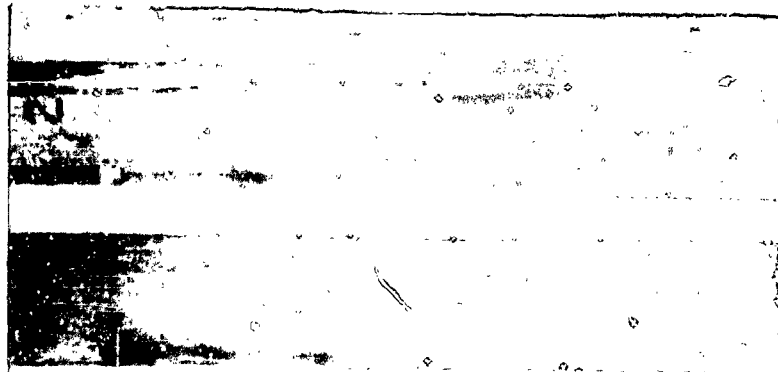




Fig. 39. - Illustration of lumber imperfections. Comparative hardwood specimens of acceptable and not acceptable deckboards.

No. 1. - Hit and miss surfaced area - acceptable manufacturing imperfection, fine season checks (lengthwise separation of the wood) not exceeding in length the width of the deckboard - acceptable.

No. 2. - Fine season checks not exceeding in length the width of the deckboard - acceptable.

No. 3. - Large season checks - exceeding in length the width of the deckboard - not acceptable.

Neg. No. 321-7.

Fig. 40. - Comparative hardwood specimens of acceptable and not acceptable deckboards.

No. 1. - Wane (bark) on edge of deckboard does not exceed the edge thickness of the board - acceptable.

No. 2. - Wane (bark) on edge of board exceeds the edge thickness of the board - not acceptable.

Neg. No. 321-8.



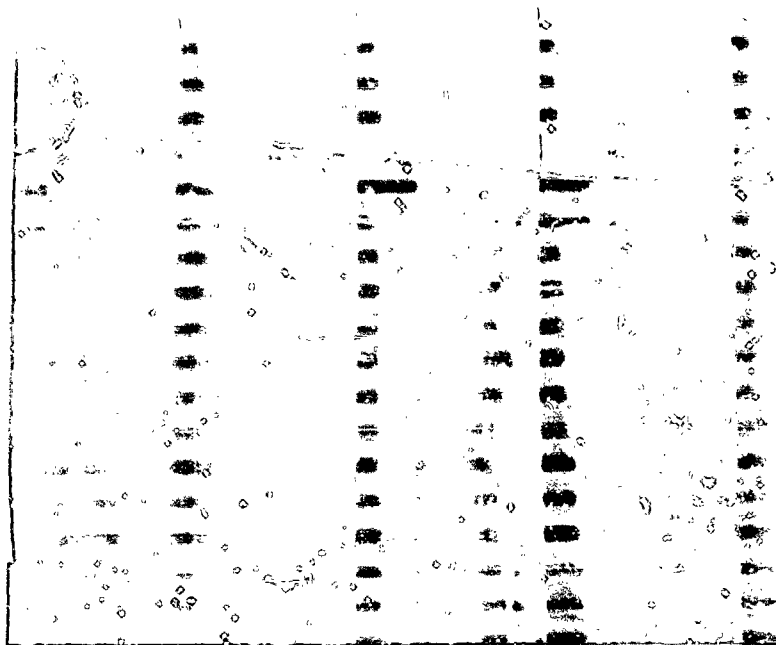


Fig. 41. - Illustration of reasons for pallet rejection by military inspector. Any one of the four defects illustrated is ample cause for rejection due to high pallet maintenance costs which would otherwise have to be borne by using activity. 4-way 40" x 48" pallet (partial entry) - not acceptable. Defect No. 1. - excessive wane (bark) entire top surface length of stringer. Defect No. 2. - scar damage on large area grown over curl of tree. Defect No. 3. - splits (lengthwise separation of deckboard) exceeding in length the width of the deckboard. Defect No. 4. - (not numbered) - spacing of deckboards exceeds 1 1/2 inches. Neg. No. 321-9.

Fig. 42. - Comparative hardwood specimens of acceptable deckboards.

No. 1. - Mineral streaks and stains (chemical discoloration of wood) and sound knot - diameter not exceeding one-third the width of the deckboard - acceptable.

No. 2. - Mineral stains - chemical discoloration of wood - acceptable.

No. 3. - Bird pecks - acceptable.

Neg. No. 321-10

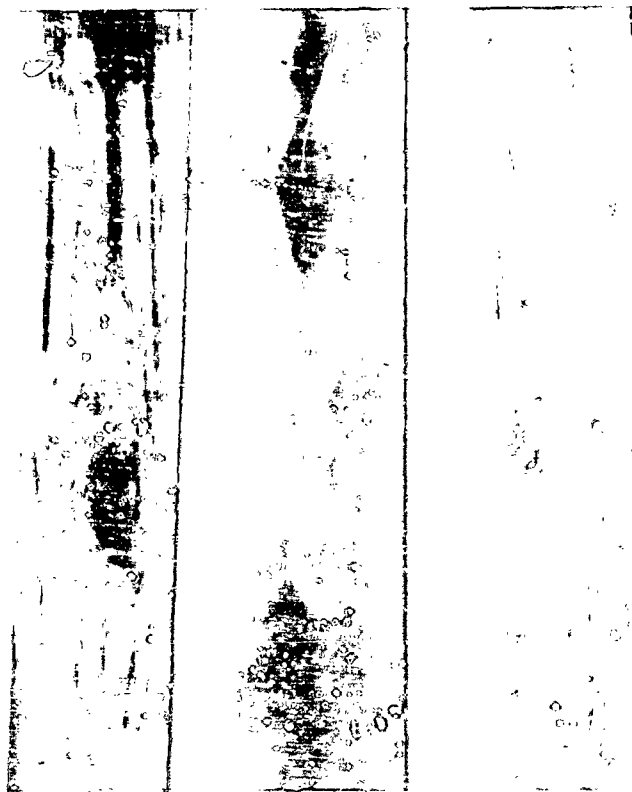




Fig. 43. -
Comparative Hardwood Specimens of Acceptable and Not
Acceptable Deckboards for Pallet Use.

No. 1. - Sound Knots - average diameter not exceeding one-third the width of the deckboard, shallow worm hole not exceeding one-half inch in diameter - acceptable.

No. 2. - Cluster of worm holes permeating deckboard and exceeding one-half inch in diameter - not acceptable.

No. 3. - Shallow worm holes not exceeding one-half inch in diameter and small sound knot not exceeding one-third the width of the deckboard and one unsound knot less than one inch in diameter - acceptable.

Neg. No. 321-11.

2.6 POSTS OR STRINGERS: The more restrictive parts of military specifications with regard to limitation of defects allowed are those pertaining to the posts or stringers. These are the pallet members to which boards are nailed and are the vertical supports of the pallet. The structural strength of the nailed wood pallet is largely dependent on these members since they not only must be able to withstand the sharp impacts of lift equipment caused by careless entry of the forks under the top deck, but must be able to provide the high nail holding qualities necessary to maintain a tight and strong pallet assembly throughout the life of the pallet. The damaging of these members is more critical than the other pallet parts. The collapse of any one of these members will render the pallet useless. In addition, the labor required to replace a damaged stringer is excessive, since a tedious and costly operation of breaking away the pallet boards at every one of the nailing points along the stringer length must be performed. Invariably, the costs involved may equal or exceed the original price of the pallet.

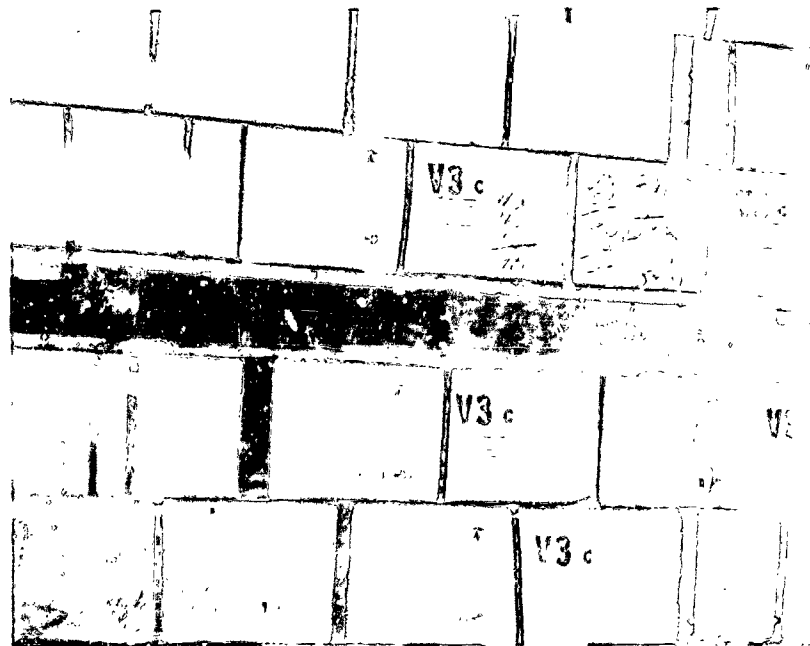


Fig. 44. - Example of damages inflicted to the post members of the pallet by the forks of the lift truck. Note how the hardwood post has been able to resist complete collapse. Neg. No. 41-4.

2.7 NAILS AND NAILING. One of the principal advantages of wood as a construction material for pallets is the ease with which it can be fastened. Nails are the simplest and most economical fastenings for wood, since they require no special tools and little, if any, mechanical skill on the part of the user. The great economic advantages secured by the use of nails in pallets, without serious sacrifice of pallet strength, have been made possible by the development of the grooved shank nail. Two distinct types of grooved shank nails are utilized for pallet specifications. The spiral groove, or what is commonly called the drive screw nail, has been established as the more effective design for pallet usage. Another groove shank nail, the annular ring type, is included for use in softwood pallet specifications. Tests conducted by the Forest Products Laboratory have shown that, under certain conditions, the grooved shank nail design will provide more than six times the resistance to direct withdrawal from wood than the common plain shank nail. More important, the resistance to withdrawal under impacts and lateral forces is almost double that of the smooth nails. These strength characteristics are essential for good pallet performance. Even with these features, the pallet so constructed is no exception to the rule that the strength of a built up wooden structure usually depends on how securely the joints are fastened.

When the special thread of the grooved shank nail is properly designed, the nail turns like a screw during driving. The grooved shank works itself into the wood by forming a thread, thus allowing the nail surfaces to turn and slide along the wood fibers. Once driven, the helically threaded nail develops considerable resistance to withdrawal because of the friction between the nail shank and the compressed wood fibers which have penetrated in and around the grooves of the nail.

From the above details, it can be seen that the thread design is of extreme importance in nail efficiency. The threads should be of sufficient depth in order to secure increased friction between the wood fibers and the nail shank. In addition, the helical angle of the thread should be such as to firmly engage the wood fibers and pull two pieces more tightly together. Certain pallet manufacturers, submitting low bids on military pallet contracts, have disregarded the specification for nail shank design and have substituted nails having a long lead angle or shallow thread in an endeavor to gain driving ease, and lower production costs. This practice can only lead to a poorly constructed pallet that will

penalize the user with high maintenance and repair costs which, in some cases, may double the original purchase cost. (See Figs. 46 to 48). It becomes mandatory, therefore, to treat the nails and nailing specifications of the pallet as one of the most important characteristics of manufacture and as an item for close scrutiny on the part of the inspector passing on the acceptability of pallet lots. Damages to pallets due to the failure of the nailed joints are a common source of trouble. Caution must be exercised to be sure that the right type, number, and size of nails are used and that the best possible nailing practices are employed in construction.

Most pallet specifications will list the required nailing pattern to be used in the fastening of the component pallet parts. Such arrangements as have been specified are those that will provide the most efficient spacing and location of nails to insure a strong joint assembly. Using the proper technique in nailing will alleviate most of the difficulties encountered when driving nails through hardwood. The Forest Products Laboratory has prepared several excellent pamphlets on this subject. They are recommended for reference and use by pallet manufacturers. These are listed as - "Technical Note No. 247", entitled, "Nailing Dense Hardwoods", and "Technical Note No. 243", entitled, "General Observations on the Nailing of Wood".

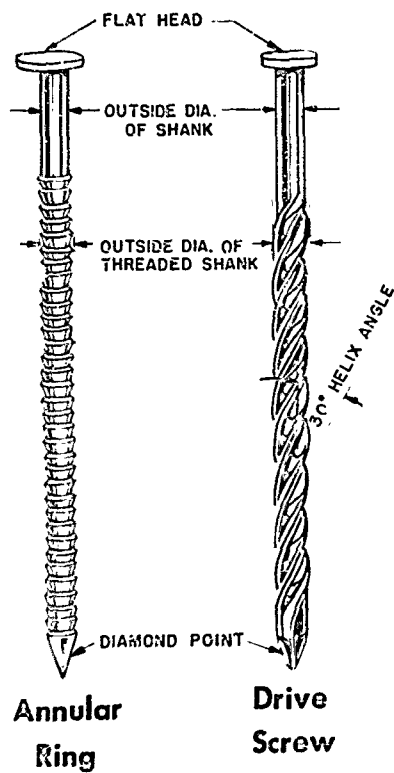


Fig. 45. - Two types of deformed shank nails utilized for wood pallet specifications. The drive screw type is used for hardwood pallets and must have the proper helix angle and depth of thread for maximum effectiveness. The annular groove nail is included in softwood pallet specifications.

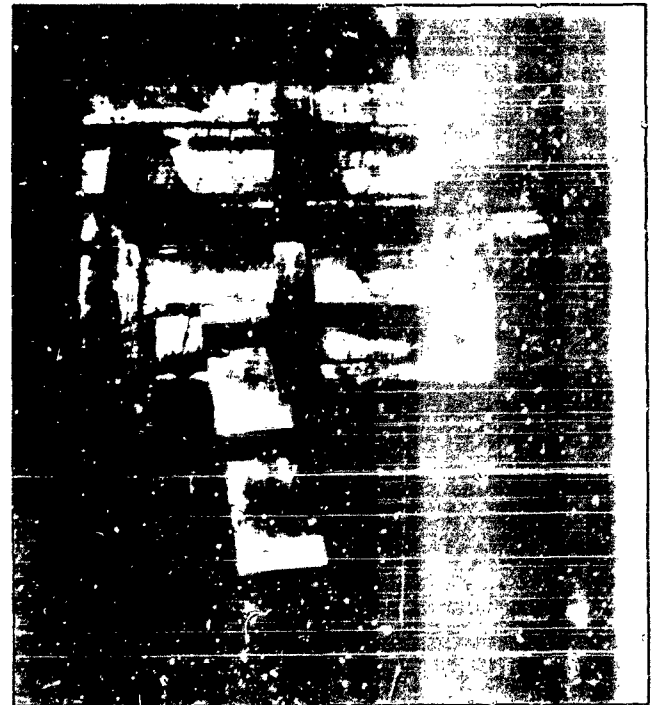
Fig. 46. - Example of non-compliance to nailing specifications by the pallet manufacturer. Improper size and amount of nails used has resulted in separation of bottom deck assembly of pallet at first handling. Early repair costs are evident. Neg. No. 30-1.





Fig. 47. - Example of splitting due to improper nailing with a serious loss of nail holding power as the result. Neg. No. 41-10.

Fig. 48. - Complete disregard of the nailing specification by a pallet manufacturer. Note that one nail has been used at each of the bearing locations requiring four. Also see splitting of the stringer board due to poor nailing methods used in construction. Neg. No. 151-4.



2.8 CONSTRUCTION AND WORKMANSHIP. Military pallet specifications include construction drawings and stipulate requirements in careful detail to provide sufficient guidance to the manufacturer in the assembly of component parts. In this one requirement, more so than in any other, the integrity and managerial ability of the supplier is clearly reflected in the finished product.

Careful workmanship should start at the cutting operations where the component wood parts are cut and selected for use. Boards, stringers and other parts should be cut square and to proper length to assure the desired rectangular dimensions specified in the construction drawing. Board thicknesses and the wood parts forming the vertical supports between the pallet decks must be of uniform dimension to insure safety of operation in the high tiering of pallet loads.

It is also in the assembly operation that opportunities exist to screen out lumber that does not meet the requirements of the specifications. Board widths should be segregated and stacked so that they may be readily selected for use in the proper location of the pallet assembly. Pallet specifications requiring certain board widths are based on advantageous and important design considerations which are necessary for operational or strength functions. For example; the end boards of the top deck may be specified for 5-5/8" widths or greater, to insure adequate strength at locations that are more susceptible to damages due to rough handling than the other board members. Other dimensional requirements of boards may be made to satisfy operational requirements, such as entry spaces for handling equipment, grooves for the insertion of steel bands for strapping of loads to the pallet, chamfering of certain bottom deck boards and space openings in the bottom deck for the wheels of the hand pallet truck. (See Fig. 52 and 53).

At this point also, attention to the run of the grain and nailing patterns will eliminate splitting, and provide a strong, operationally stable unit. Nothing could be simpler than employing a staggered pattern in driving nails, yet the failure to observe this one construction detail is responsible for more damage, pallet failure expensive repairs than any other single requirement.

Nails should be driven below the board surface and bent nails pulled or broken off below the surface so that bags and other merchandise are not damaged when placed on the pallet.

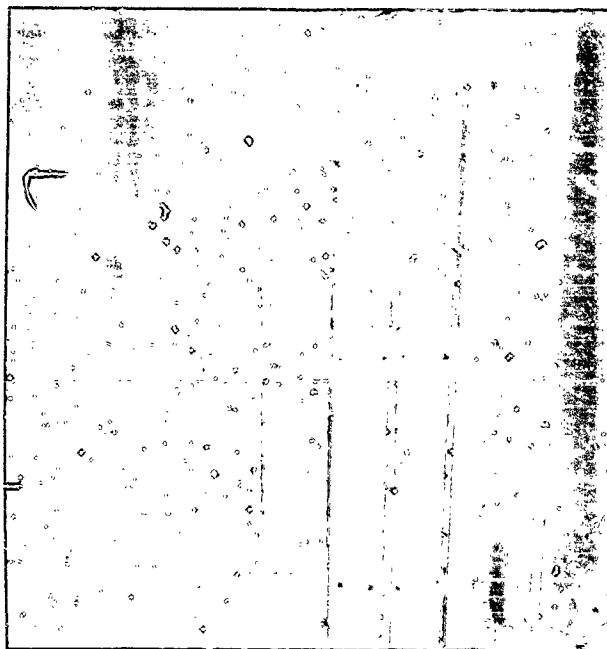


Fig. 49. - Example of poor workmanship of pallet construction. Note non-parallel sides of pallet, improper board spacing and irregular board width and lengths. Neg. No. 600-7.

Fig. 50. - Pallet specification lists 1" minimum to 1-1/2" maximum board spacing. Note complete disregard in spacing deck-boards by this pallet manufacturer and poor workmanship in construction. Neg. No. 600-12.

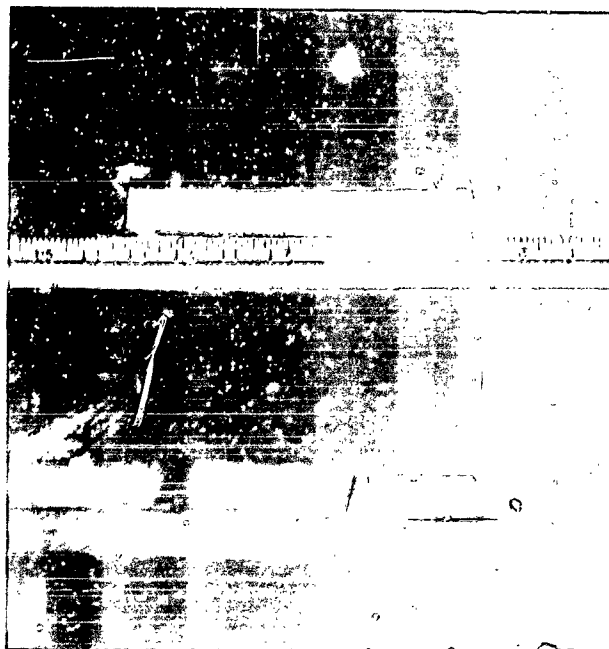




Fig. 51. - Another example of poorly constructed pallets. In addition to excessive defects in lumber, note non-alignment of stringer boards with posts. Neg. No. 106-60

Fig. 52. - Chamfering of the bottom deck boards is required to permit the small wheels of the hand pallet truck to easily ride over when entering for the pickup. Neg. No. 151-3.



The spacing of top deck boards is another critical design element. The following are the controlling considerations:

1. Structural strength - Requires as many board feet of lumber as possible.
2. Economy - Requires as little lumber as practicable.
3. Ventilation and Cleanliness - Requires wide, frequent spaces between boards.
4. Maximum bearing surface - Requires as much covered area as possible.

The spacings selected and specified are those disclosed by investigations to be the most compatible with the above requirements.



Fig. 53. - Slots are required in the pallet for the insertion and passing through of steel bands for strapping unit loads to the pallet. Note strapped pallet load at bottom. Neg. No. 151-2.

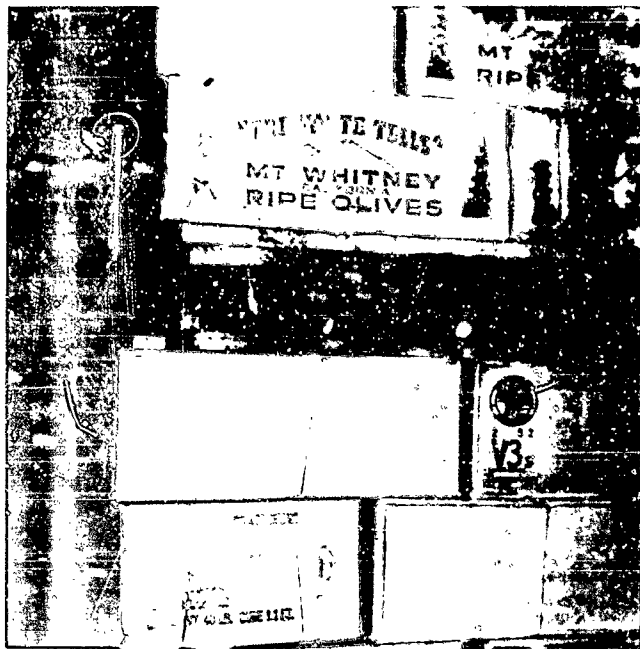
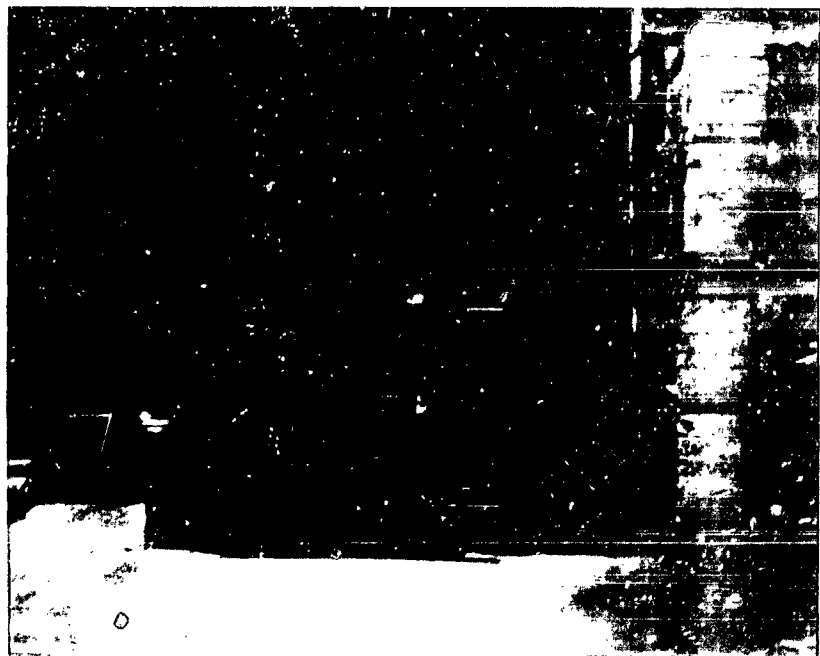


Fig. 54. - Example of faulty workmanship in the selection of material for the pallet's posts. Note lack of wood bearing area for nailing and load support in the most important structural member of the pallet assembly. Neg. No. 41-8.

Fig. 55. - Actual photograph of a pallet scrap heap. Most damaged pallets are the result of poor workmanship and nailing techniques at the time of pallet manufacture. Neg. No. 151-1.



2.9 PALLET INSPECTION CHECK LIST. The following inspection report form has been prepared primarily to effect a method wherein inspection of nailed wood pallets may be standardized. It is intended to be used by pallet inspectors and manufacturers as a system of checking items of specification and contract requirements in military pallet procurements.

PALLET INSPECTION CHECK-LIST

PALLET NUMBER	MATERIAL				QUALITY				WORKMANSHIP				Total Defects									
	Specified woods only	Moisture content	Nails - type and size	Advanced decay	Excessive warp	Pitch and holes	Shakes or bark	Knots and season checks	Cup or twist	Specified length	Specified thickness	Exposed surfaces dressed		Boards parallel to sides	Pallet perfect cut	Center bottom rectangle	Chipped or torn boards	Chamfering and wood grain	All pieces S2S	Deckboard spacing	Branding	Nailing
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COMMENT ON REVERSE

**DEPARTMENT OF DEFENSE
PALLET INSPECTION CHECK-LIST**

This Inspection Check-List is furnished as a guide to the Inspector and as an aid to tabulation of defects. Before inspecting any lot of pallets, the Inspector should have with him a copy of the applicable specification and be thoroughly familiar with each element thereof.

Applicable Specification Number: _____

Contract Number: _____

Contractor's Name: _____

Address: _____

Delivery Destination: _____

Lot Number: _____

of _____

lots.

Number of Pallets Inspected: _____ Number of defective pallets allowed: _____ No. defective in lot: _____

ACCEPTED/REJECTED

Date: _____

(Inspector's Signature)

INSPECTOR'S COMMENTS:

DEPARTMENT OF DEFENSE

- - - -

PALLET INSPECTION
CHECK LIST

- - - -

The following specifications are applicable to this check list and the inspector should be thoroughly familiar with such specifications. This check list is not intended as a replacement for, but rather as a guide to utilization of the specification:

MIL-P-15943 (S and A) Amend. 2 - 3 May 1951
MIL-P-15011C (S and A) - 28 Jan. 1953
MIL-P-16496 (S and A) - 27 July 1951
Fed. Spec. NN-P-71 - 23 Sept. 1947

PALLET NUMBER	Are specified woods used throughout?	Is all lumber sound, free of advanced decay or excessive warp?	Is pith firm and tight?	Is wane or bark on all pieces within specified range?	Are shakes within allowance?	Are season checks within allowance?	Are all holes within specified allowance?	Are all knots and knotholes within specified size?	Are all splits within specified range?	Is cup or twist within specified allowance?	Is chipped or torn grain within specified allowance?	Are all pieces of specified length?	Are all pieces of specified thickness?	Are all pieces of specified width?	Are all boards S2S with saw marks removed?	Do center bottom board(s) meet specifications?	Is the volume content of
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3																	
4																	
5																	
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Defects

A

SECTION III

INSPECTION OF LUMBER FOR PALLETS

By

Forest Products Laboratory,¹ Forest Service
U. S. Department of Agriculture

FOREWORD

This section was prepared by the Forest Products Laboratory at the request of the U. S. Naval Supply Research and Development Facility, Naval Supply Depot, Bayonne, N. J. Staff members of the Forest Products Laboratory who assisted in planning and preparing the material for this manual are:

JOSEPH A. LISKA, Engineer
LYMAN W. WOOD, Engineer
RAMON J. HEICK, Engineer

¹
Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Purpose and Scope

This publication has been prepared to aid inspectors of pallet lumber for the Armed Forces by presenting fundamental information about wood upon which grading and inspection rules are based. Understanding of such grading rules, and their application to pallet lumber, depends to a great extent upon the inspector's basic knowledge of wood properties, characteristics, and growth variables.

The grades of lumber used in pallet manufacture may be characterized by the grosser kinds and sizes of defects, such as knots, checks, and decay, and thorough inspection becomes essential if serviceable pallets are to be obtained. Lower grades of lumber are economical for pallets because much short-length material suitable for pallets is obtainable by judicious cutting and by positioning of pallet members, so that defects are either eliminated or so placed in the finished pallets that they do not critically impair strength and serviceability.

The information in this publication was assembled for the purpose of giving inspectors the background information needed to determine whether lumber has been properly cut and assembled to assure a strong, serviceable pallet. The species commonly used for pallets are listed and their important characteristics outlined. Defects that affect strength and service life are described. The important wood properties are treated briefly, and the effects of moisture and shrinkage are explained.

3. Nature of Wood

3.1 General Structure

Wood consists mainly of hollow fibers built up of interconnected cellulose chains arranged spirally in the long direction of the fibers. In the walls of the fibers and other cells is a material called lignin, which also binds the cells together so firmly that wood breaks usually within the fiber walls rather than in the bond between the fibers. Therefore, for mechanical purposes wood may be considered as made up of tubes of indefinite length firmly welded together rather than separable fibers of varying lengths.

Unlike metals, which have generally uniform strength in all directions and whose every cubic inch is identical, wood has not, for instance, the same strength across the grain as parallel to the grain; that is, its tensile strength may vary as much as 40 to 1, its crushing strength 7 to 1, and its modulus of elasticity 150 to 1. Not only do different species of wood differ in their properties, but trees of the same species and even parts of the same tree may vary, depending on the growth conditions prevailing when the wood was formed.

3.2 Heartwood and Sapwood

In most wood, three regions are readily discernible in the end surface of the log: (1) The bark; (2) the light-colored sapwood next to the bark; and (3) the heartwood, which is usually darker than the sapwood (Fig. 56). In the structural center of the tree trunk there is a small, soft core--the pith.

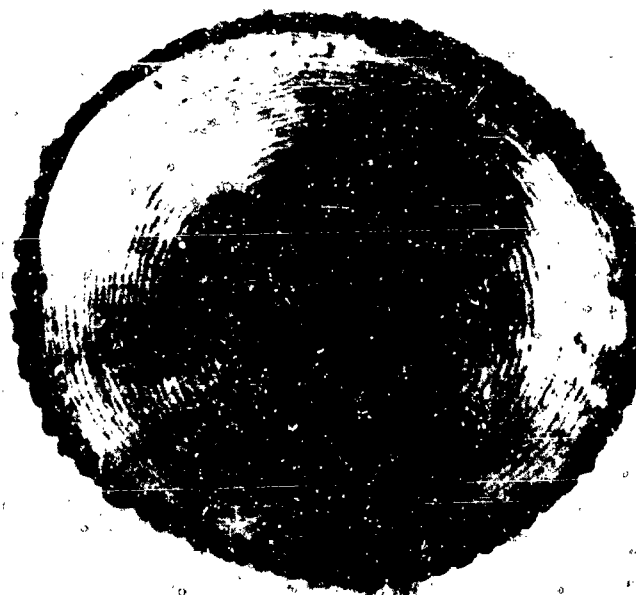


Fig. 56. - Cross section of white ash log, showing irregular-shaped heartwood (dark) at center, wide sapwood (light), and bark (black outer-most layer). (M6919F)

In the sapwood many of the cells (parenchyma) are alive and serve mainly in the transfer and storage of food, which accounts

in part for the greater susceptibility of sapwood to attack by certain fungi and insects. Most of the cells, however, are dead and serve only as channels for the movement of sap and to strengthen the tree trunk. In the heartwood all of the cells are dead and function mainly to strengthen the trunk.

In some woods there is little or no difference in color between heartwood and sapwood. Spruce (except Sitka spruce), hemlock, the true firs, Port-Orford-cedar, basswood, cottonwood, and beech are examples of this class. In other woods, such as pine, Douglas-fir, baldcypress, ash, oak, maple, birch, and sweetgum, there is a well-marked contrast between sapwood and heartwood.

Although sapwood is, as a rule, light-colored, it may be discolored by sap stain, wood-destroying and other fungi, chemical stains within the wood, and color leached from the bark. The heartwood may be uniform in color or streaked or variegated, as is often the case in sweetgum. Heartwood infected with decay may be discolored in various ways.

Light-colored zones, known as internal sapwood, are occasionally found in the heartwood of Douglas-fir, Sitka spruce, western redcedar, western larch, and other species.

The thickness of the sapwood layer varies considerably in different species. In black ash, black cherry, northern white-cedar, western redcedar, Douglas-fir, and spruce, it is usually less than 1-1/2 inches and consequently constitutes a relatively small part of the lumber cut from these species. In white ash, birch, maple, and hickory, the sapwood is so thick that it often comprises more than one-half of the lumber produced.

Heartwood is not fundamentally weaker or stronger than sapwood, but there are some changes in physical characteristics, besides change in color, that accompany heartwood formation. After the timber is cut, the heartwood usually is more resistant to the attack of certain insects and to decay, stain, and mold than the sapwood. In the living tree the sapwood is usually less subject to attack, whereas specific fungi often infect the heartwood. Heartwood is less permeable to liquids, as a rule, which is an advantage in many uses but a disadvantage in the injection of preservatives. Because it is less permeable, heartwood seasons at a slower rate than the sapwood. In resinous species, such as the yellow pines, the heartwood usually contains more resin than the sapwood.

3.3 Annual Rings

In timber grown in temperate climates, well-defined concentric layers of wood can be seen on the cross section. These layers correspond closely to yearly increments of growth, and for that reason are called annual rings (Fig. 57). The width of the annual rings varies with the environmental conditions, such as stand density and soil moisture, under which the trees grew.

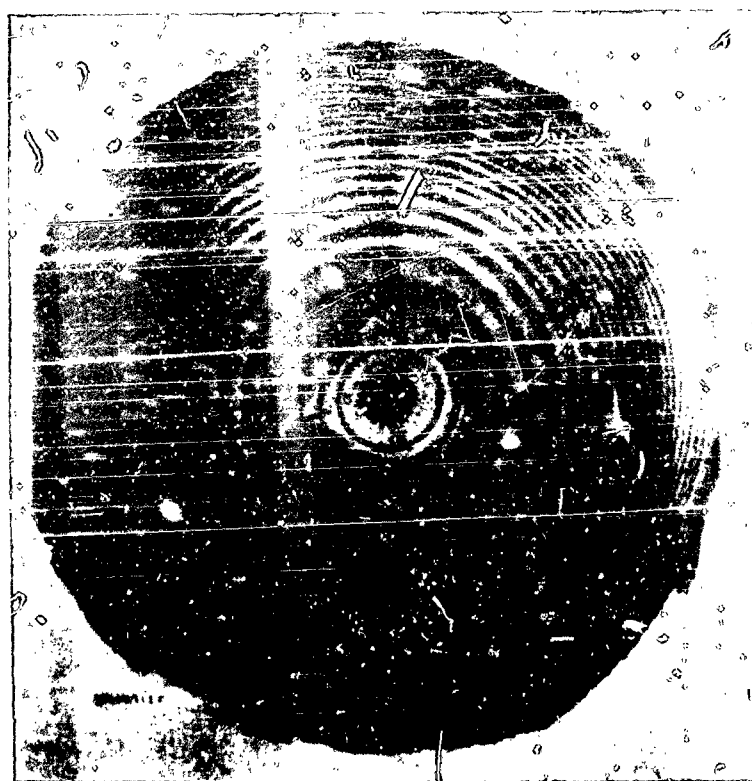


Fig. 57. - Cross section of a southern yellow pine log, showing annual growth rings. Each light ring is springwood. Each dark ring is summerwood. The dark spot at the center is the pith. (ZM10712F)

Springwood is the wood formed on the inner side of the annual ring during the early part of each growing season. It is usually more porous, softer, weaker, and, especially in the conifers (softwoods), lighter in color than the summerwood, which is formed in the outer part of the annual ring during the later part of the growing season. Segments of annual rings in a cross section of Douglas-fir, magnified 20 diameters, are shown in

Fig. 58. Springwood and sapwood may be fairly sharply differentiated from each other within each annual ring, as in Douglas-fir and oak, or the transition may be gradual, as in walnut. In some woods (for example, yellow-poplar, birch, maple, basswood, cottonwood, and sweetgum) the transition from springwood to summerwood within the annual ring is not clear, although the division between rings is distinct.

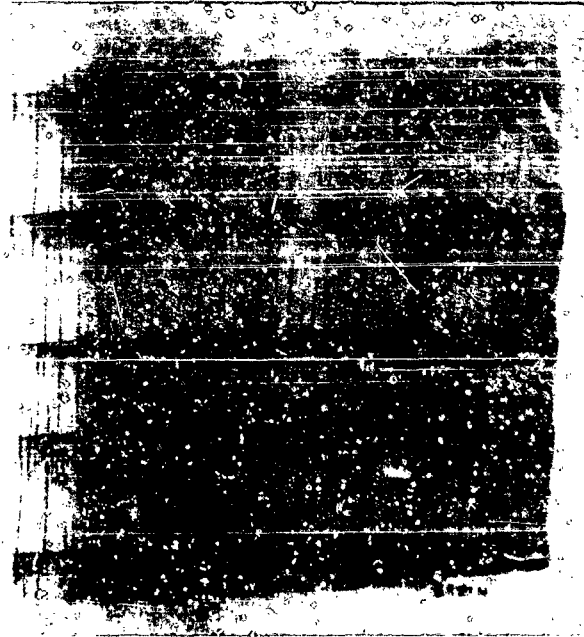


Fig. 58. - Cross section of Douglas-fir magnified 20 diameters. (2281M)

The width of the summerwood and the percentage that it occupies in the total width of the annual rings varies considerably in some species, such as yellow pines, Douglas-fir, oaks, ashes, and hickories, according to the vigor of the tree at the time the rings were formed.

3.4 Plain-sawed and Quarter-sawed Lumber

Wood can be cut in three distinct planes with respect to the annual growth rings: (1) Crosswise, exposing the transverse or end-grain surface; (2) lengthwise along any of the radii of the annual rings, exposing the radial or so-called quarter-sawed, edge-grain, or vertical-grain surface; and (3) lengthwise tangent to any of the annual rings, exposing the tangential or so-called plain-sawed or flat-grain surface. Quarter-sawed and plain-sawed boards are shown in Fig. 59.

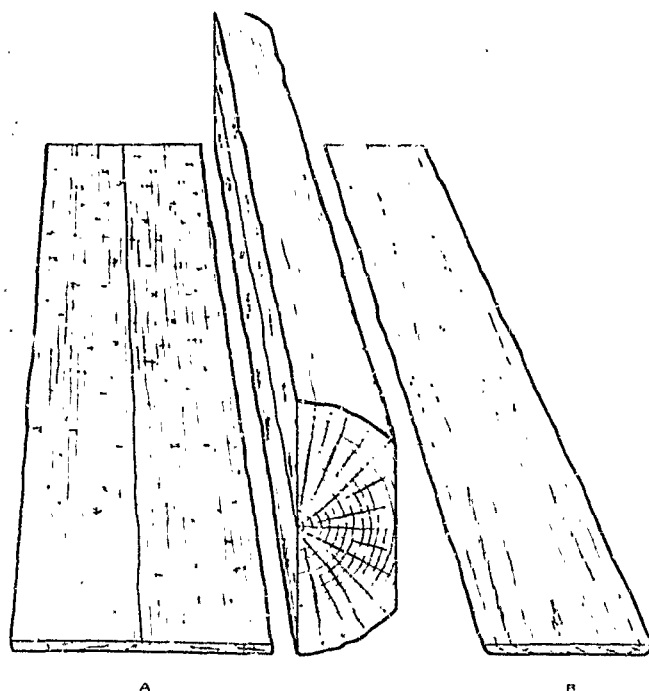


Fig. 59. - Quarter-sawn (A) and plain-sawn (B) boards cut from log. (ZM554F)

Quarter-sawn lumber shrinks and swells less in width and twists, cups, slivers, surface checks, and casehardens in seasoning less than plain-sawn lumber. On the other hand, plain-sawn lumber is cheaper to produce and does not "collapse" so easily in drying; also, any knots that are present are round or oval instead of long spike knots.

The annual rings often run diagonally across the end of a board so that it cannot be said to be either strictly plain-sawn or quarter-sawn. Squared dimension stock may show two plain-sawn and two quarter-sawn faces, or four faces of an intermediate form.

3.5 Grain and Texture

The terms "grain" and "texture" are used rather loosely in connection with lumber. "Grain" is used in referring (1) to the annual rings, as coarse, fine, even, edge, and flat grain; (2) to

the direction in which the fibers run, as straight, spiral, interlocked, wavy, and curly grain; and (3) to the relative size of the pores and the fibers, as open grain and close grain.

"Texture" is often used synonymously with grain. More specifically, it is used to designate woods having small and closely spaced pores as fine-textured woods or woods having large pores as coarse-textured woods.

3.6 Weight of Wood

Table 1 shows the average weights of the more important woods used for pallets. Tabulated weights of green wood include the moisture present in the trees as felled. The weights for air-dry wood were determined at a moisture content of 12 percent, representing the moisture condition reached by lumber in unheated covered sheds in the North Central States.

In any lot of air-dry lumber of a given species, at 12 percent moisture content, the weight per cubic foot will rarely vary more than 10 percent from the figure shown in table 1. In green lumber, on the other hand, the variation may occasionally be as great as 20 percent, owing to wide differences in moisture content. Particularly in species that have a high moisture content in the sapwood, large variations in weight when green may occur, depending on the proportion of sapwood. Since young softwood trees contain a larger proportion of sapwood than old trees, their wood averages heavier when green.

3.7 Decay Resistance

Wood kept constantly dry, at a moisture content of less than 20 percent, does not decay, regardless of species or of the presence of sapwood. Therefore, when pallets are used for protected storage, where they will remain dry, decay resistance of the wood is not an important consideration. With unprotected outdoor storage, however, decay resistance is a significant factor in pallet serviceability. When exposed to conditions that favor decay, as in a warm, wet climate, woods of low decay resistance may last less than a year, but the heartwood of highly resistant species may give several years of service, even up to 15 years. When outdoor exposure is less severe, several years of service may also be expected from the woods of low decay resistance.

In all woods, the sapwood has very low decay resistance, but the heartwood may have high or low resistance, depending on the species. The heartwood of the cedars, redwood, cypress, black locust, and black walnut has a high natural resistance to decay. The heartwood of white oak is also very resistant to decay. Other common species have heartwood of intermediate to low decay resistance.

3.8 Hardwoods and Softwoods

Native species of trees are divided into two classes--hardwoods, which have broad leaves, such as the oaks and maples, and softwoods, which have scalelike leaves, such as the cedars, or needlelike leaves, such as the pines. Hardwoods, except in the warmest regions, are deciduous; that is, they shed their leaves at the end of each growing season. Native softwoods, except cypress, tamarack and larch, are evergreen. Softwoods are known also as conifers, because all native species of softwoods bear cones of one kind or another.

The terms "hardwood" and "softwood" have no direct application to the hardness or softness of the wood of the two classes. In fact, such hardwood trees as cottonwood and aspen have softer wood than the white pines and true firs, and certain softwoods, such as longleaf pine and Douglas-fir, produce wood that is as hard as that of basswood and yellow-poplar.

Fig. 60 shows the principal types of forests in the United States and may be helpful in identifying pallet species when the locality of growth is known.

Since either softwoods or hardwoods may be used in the fabrication of pallets, it is frequently desirable to separate the two classes, depending upon specification requirements.

Although the differences between hardwoods and softwoods are quite marked when the wood is examined with a hand lens or microscope, they may not be so apparent when viewed with the naked eye. Because the number of species employed in pallets is relatively small, it is possible to distinguish between softwoods and hardwoods on the basis of the appearance of their annual rings.

In softwoods, the annual rings are made up of two more or less distinct parts: The harder, darker summerwood and the soft, lighter-colored springwood. The color difference is usually quite

apparent, and the degree of hardness can readily be observed by denting with the thumbnail.

The hardwood species can be divided into two groups on the basis of their pores, which are the small, round openings visible on a cross section of the wood smoothly cut with a sharp knife. The pores are sometimes large enough to be seen by the eye, or if smaller, can be seen under a 10-power magnifying glass.

In ring-porous woods, such as the oaks and ashes, the pores are much larger in the springwood than in the summerwood. The annual rings in this group are very apparent because of the difference in the degree of porosity between the two zones making up an annual ring. In the other group of hardwoods, the pores are more or less uniform in size throughout the annual ring, and the group is called diffuse-porous. Although this group may sometimes be confused with the softwoods, it does not have the marked difference in hardness between the springwood and summerwood that is found in the softwood species. Diffuse-porous species include the maples, birches, beech, and magnolia, and in all these species the pores are not visible to the naked eye. In the majority of the diffuse-porous hardwoods, the annual rings can generally be distinguished but are not so clearly marked as they are, for example, in Douglas-fir and southern yellow pine.

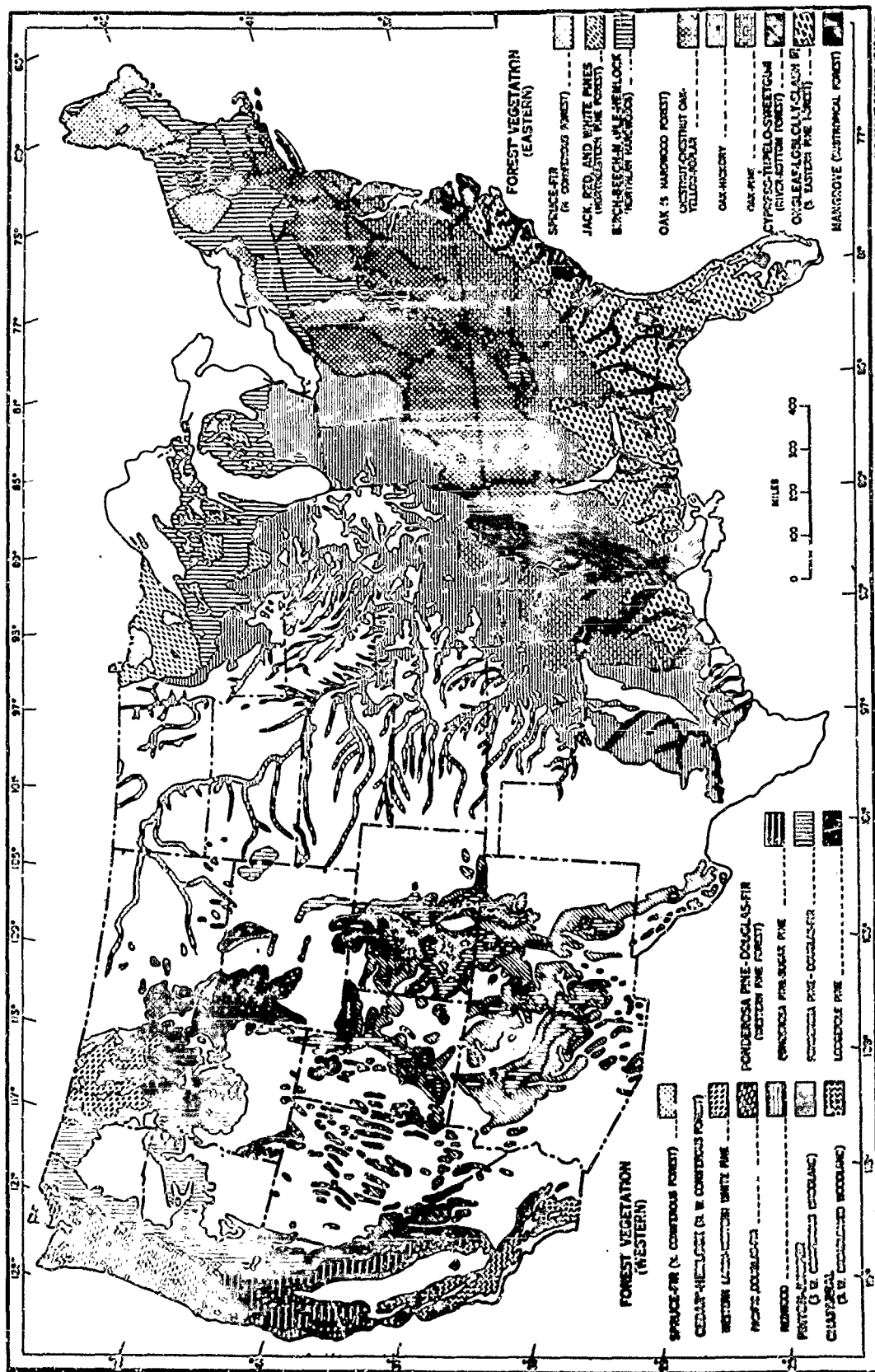


Fig. 60. - Principal types of forest in the United States

SECTION IV

4. Principal Woods Used for Pallets

The following brief discussion of the localities of growth and properties of the principal woods used for pallets will aid in their identification and selection for specific purposes.

Hardwood Pallet Species

4.1 Ash

Important species of ash are white ash (Fraxinus americana), green ash (Fraxinus pennsylvanica), blue ash (Fraxinus quadrangulata), Biltmore ash (Fraxinus biltmoreana), black ash (Fraxinus nigra), pumpkin ash (Fraxinus profunda), and Oregon ash (Fraxinus oregona). The first six of these species grow in the eastern half of the United States. Oregon ash grows along the Pacific coast.

Commercial white ash is a group of species that consists mostly of white ash and green ash. Biltmore ash and blue ash are also included in this group.

States with the greatest production of ash are Louisiana, Pennsylvania, Wisconsin, Michigan, Ohio, and Tennessee. All States east of the Great Plains produce some ash lumber.

Heartwood of commercial white ash is brown; the sapwood is light-colored or nearly white. Second-growth trees have a large proportion of sapwood. Old-growth trees with little sapwood are scarce. Heartwood of black ash is mostly dark colored.

4.2 Beech

Only one species of beech (Fagus grandifolia) is native to the United States. The terms "red beech" or "red-heart beech" are applied to the darker-colored heartwood and "white beech" or "white-heart beech" to the lighter-colored heartwood.

Beech grows in the eastern one-third of the United States and adjacent Canadian provinces. Greatest production of beech lumber is in the Central and Middle Atlantic States. The Southern States contribute over one-fifth of the total production and lesser amounts come from Michigan and the New England States.

Beech wood varies in color from nearly white sapwood to reddish-brown heartwood in some trees. Sometimes there is no clear line of demarcation between heartwood and sapwood. Sapwood may be 3 to 5 inches thick. Growth rings are usually distinct but not conspicuous. The wood has little figure and is of close, uniform texture. It has no characteristic taste or odor.

The wood of beech is classed as heavy, hard, strong, high in resistance to shock, and highly adaptable for steam bending. Beech has large shrinkage and requires careful drying. It machines smoothly, wears well, and is rather easily treated with preservatives. Beech is low in decay resistance.

4.3 Birch

The important species of birch are yellow birch (Betula alleghaniensis), sweet birch (Betula lenta), and paper birch (Betula papyrifera). Other birches of some commercial importance are river birch (Betula nigra), gray birch (Betula populifolia), and western paper birch (Betula papyrifera var. occidentalis).

Yellow birch, sweet birch, and paper birch grow principally in the Northeastern States and Lake States. Yellow and sweet birches also grow along the Appalachian Mountains to northern Georgia. They are the sources of most birch lumber and veneer. Production of birch lumber is highest in the Lake States, followed by the New England and Middle Atlantic States.

Yellow birch has white sapwood and light reddish-brown heartwood. Sweet birch has light-colored sapwood and dark-brown heartwood tinged with red. Wood of yellow birch and sweet birch is heavy, hard, strong, and has good shock-resisting ability. The wood is fine and uniform in texture. Paper birch is lower in weight, softer, and lower in strength than yellow and sweet birch. Birch shrinks considerably during drying and is low in natural resistance to decay.

4.4 Elm

There are six species of elm in the United States: American elm (Ulmus americana), slippery elm (Ulmus rubra), rock elm (Ulmus thomasi), winged elm (Ulmus alata), cedar elm (Ulmus crassifolia), and September elm (Ulmus serotina). American elm is also known as white elm, water elm, and gray elm; slippery elm as red elm; rock elm as cork elm or hickory elm; winged elm as Wahoo; cedar elm as red elm or basket elm; and September elm as red elm.

American elm grows throughout the eastern half of the United States, except in higher elevations of the Appalachian Mountains. Slippery elm, occupies about the same area, excepting the Atlantic Coastal Plain, most of Florida, and along the Gulf coast. Rock elm occurs from New Hampshire to northern Tennessee and Nebraska. Winged elm grows from the Ohio Valley southward to the Gulf, except in southern Florida, and westward to eastern Texas. Cedar elm extends from southern Arkansas and eastern Mississippi into Texas. Slippery elm is most abundant in the central Mississippi Valley.

The sapwood of the elms is nearly white and generally quite thick, except in slippery elm where it rarely exceeds one-half inch in thickness. The heartwood of elm is light brown, often tinged with red. The elms may be divided into two general classes, hard elm and soft elm, based on the weight and strength of the wood. Hard elm includes rock elm, winged elm, cedar elm, and September elm. American elm and slippery elm are the soft elms. Soft elm is moderately heavy, has a high degree of shock-resisting ability, and is moderately hard and stiff. Hard elm species are somewhat heavier than soft elm. Elm is moderately resistant to decay and requires care in drying. It has excellent bending qualities.

4.5 Hackberry

Hackberry (Celtis occidentalis) and sugarberry (Celtis laevigata) supply the lumber known in the trade as hackberry. Hackberry grows east of the Great Plains from Alabama, Georgia, Arkansas, and Oklahoma northward, except along the Canadian boundary. Sugarberry overlaps the southern part of the range of hackberry and grows throughout the Southern and South Atlantic States. The wood of the two species is similar and is not separated in the trade.

The sapwood of both species is 3 or more inches wide and varies from pale yellow to greenish or grayish yellow. Heartwood is commonly darker in color. Growth rings are distinct. The wood resembles elm in structure.

Wood of hackberry is moderately heavy, moderately strong in bending, moderately weak in compression parallel to the grain, moderately hard to hard, high in shock resistance, but low in stiffness. It has moderately large to large shrinkage but keeps its shape well during seasoning.

4.6 Hickory, True and Pecan

True hickories are found throughout most of the eastern half of the United States. The species most important commercially are shagbark (Carya ovata), pignut (Carya glabra), shellbark (Carya lacini-osa), mockernut (Carya tomentosa), and red hickory (Carya ovalis).

Species of the pecan group include bitternut hickory (Carya cordi-formis), pecan (Carya illinoensis), water hickory (Carya aquatica), and nutmeg hickory (Carya myristicaeformis). Bitternut hickory grows throughout the eastern half of the United States. Pecan hickory grows from central Texas and Missouri and Indiana. Water hickory grows from Texas to South Carolina. Nutmeg hickory occurs principally in Texas and Louisiana.

The greatest commercial production of the true hickories is in the Middle Atlantic and Central States. The Southern and South Atlantic States produce nearly half of all hickory lumber, which includes lumber from pecan hickories as well as from true hickories.

Sapwood of true hickory is white and usually quite thick, except in old, slowly growing trees. Heartwood is reddish. From the standpoint of strength, no distinction should be made between sapwood and heartwood having the same weight.

The wood of true hickory is very tough, heavy, hard, and strong, a combination not found in any other native commercial wood. Hickory is low in natural resistance to decay and shrinks considerably in drying. Because of its hardness, hickory does not nail easily when thoroughly dry.

The wood of pecan hickory resembles that of true hickory. It has white or nearly white sapwood, which is relatively wide, and somewhat darker heartwood. Like true hickory, it is typically

ring porous. The wood is heavy to very heavy and sometimes has very large shrinkage. Heavy pecan hickory overlaps the lowest true hickory in weight and in many strength properties.

4.7 Maple

Commercial species of maple in the United States include sugar maple (Acer saccharum), black maple (Acer nigrum), silver maple (Acer saccharinum), red maple (Acer rubrum), boxelder (Acer negundo), and bigleaf maple (Acer macrophyllum). Sugar maple is also known as hard maple, rock maple, sugar tree, and black maple; black maple as hard maple, black sugar maple, and sugar maple; silver maple as white maple, river maple, water maple, and swamp maple; red maple as soft maple, water maple, scarlet maple, white maple, and swamp maple; boxelder as ash-leaved maple, three-leaved maple, and cut-leaved maple; and bigleaf maple as Oregon maple.

Sugar maple grows from Maine to Minnesota and southward to northern Georgia, Alabama, Louisiana, and Texas. Black maple occupies mainly a belt from New York through southern Michigan, southward to Kentucky and westward through Iowa. Silver maple grows through most of the eastern United States, except the southern Atlantic and Gulf coasts. Red maple grows east of the Great Plains and south to the Gulf of Mexico, except for the southern tip of Florida. Boxelder grows from Minnesota to Texas, and eastward to the Middle Atlantic States. Bigleaf maple grows along the Pacific coast.

Maple lumber comes principally from the Middle Atlantic and Lake States, which together account for about two-thirds of the production. A considerable amount of maple is cut in New England and some in the South Atlantic and Southern States. Production in the New England, Middle Atlantic, and Lake States is principally hard maple.

The wood of sugar maple and black maple is known as hard maple; that of silver maple, red maple, and boxelder as soft maple. The sapwood of the maples is commonly white with a slight reddish-brown tinge. It is from 3 to 5 or more inches thick. Heartwood is usually light reddish brown but sometimes is considerably darker. Hard maple has a fine, uniform texture. It is heavy, strong, stiff, hard, resistant to shock, but has large shrinkage. It is generally straight-grained, but some trees are characterized by curly, wavy, or bird's-eye grain. Soft maple has con-

siderably wider sapwood and lighter-colored heartwood than hard maple, and is not so heavy as hard maple. Bigleaf maple is intermediate between soft maple and hard maple in strength properties.

4.8 Oak, Red

Among the numerous species of red oaks in the United States, 10 have considerable commercial importance.

(1) Northern red oak (Quercus rubra), also known as eastern red oak, grows in the eastern half of the United States, to the lower Mississippi Valley, Florida, and the Atlantic Coastal Plain. It is the most important lumber tree of the red oak group.

(2) Scarlet oak (Quercus coccinea) grows in the eastern third of the United States, except the southern border States and the northern-most portions of New York, Vermont, New Hampshire, and Maine.

(3) Shumard oak (Quercus shumardii), also known as Schneck oak, Texas oak, and southern red oak, grows chiefly along the Atlantic and Gulf coasts, and in the Mississippi Valley.

(4) Pin oak (Quercus palustris), also known as swamp oak, grows principally in the central Mississippi Valley, and eastward to the Atlantic coast.

(5) Nuttall oak (Quercus nuttalli) grows in the lower Mississippi Valley region from Missouri southward, and from Alabama to Texas.

(6) Black oak (Quercus velutina), also known as yellow oak, grows in the eastern half of the United States.

(7) Southern red oak (Quercus falcata) grows in southeastern United States from New Jersey to Missouri, Arkansas, and Texas.

(8) Water oak (Quercus nigra) grows in the South Atlantic and Gulf States from Maryland to Texas.

(9) Laurel oak (Quercus laurifolia) grows in the South Atlantic and Gulf Coastal Plains from Maryland to Louisiana.

(10) Willow oak (Quercus phellos) grows along the Atlantic and Gulf coasts and in the lower Mississippi Valley.

Most red oak lumber comes from the Southern States, the southern mountain regions, and the Atlantic Coastal Plain.

Sapwood is nearly white in color and from 1 to 2 or more inches thick. Heartwood is brown with a tinge of red. Red oaks are all ring porous and have distinct growth rings. Sawed lumber of the various species of red oak cannot be separated on the basis of the characteristics of the wood alone. Red oak lumber can be separated from white oak, however, by the absence of the froth-like growth known as tyloses in the pores, and by the larger size of the summerwood pores. If these pores are plainly visible as minute, round openings and can be readily counted under a hand lens, the wood belongs to the red oak group. Quarter-sawed lumber of the oaks is distinguished by the broad and conspicuous rays, which add to its attractiveness.

Wood of the red oaks is heavy. Rapidly grown second-growth oak is generally harder and tougher than finer-textured old-growth timber. The red oaks have fairly large shrinkage in drying.

4.9 Oak, White

There are nine commercially important species of the white oak group, and all grow mainly in the eastern United States.

(1) White oak (Quercus alba) grows throughout the eastern half of the United States and adjacent Canada, except in the Florida Peninsula and the Mississippi River Delta. It is the most important lumber tree of the white oak group.

(2) Chestnut oak (Quercus prinus), also known as rock chestnut oak or rock oak, grows from southern Vermont and New Hampshire, southward along the Appalachian Mountains to central Georgia and Alabama.

(3) Post oak (Quercus stellata) grows throughout the eastern half of the United States from southern New England southward to the Great Plains.

(4) Overcup oak (Quercus lyrata), also known as swamp white oak, grows in the Atlantic Coastal States and westward to Texas through southern Illinois and Indiana.

(5) Swamp chestnut oak (Quercus michauxii), also known as basket oak and cow oak, grows along the Atlantic coast and westward to Texas through southern Illinois and Indiana.

(6) Bur oak (Quercus macrocarpa) grows mainly from New York to Montana and southward through Kentucky to Texas.

(7) Chinkapin oak (Quercus muehlenbergii) grows from New York, southern Michigan, and southern Minnesota southward to the Gulf of Mexico, except for the Atlantic Coastal Plain and Florida.

(8) Swamp white oak (Quercus bicolor) grows from southern Maine through the Central States to the Great Plains.

(9) Live oak (Quercus virginiana) is limited to the Atlantic Coastal Plain, Florida, and the Gulf Coast, extending across the southern portion of Texas.

White oak lumber comes chiefly from the South, South Atlantic, and Central States, including the southern Appalachian area.

The heartwood of the white oaks is generally grayish brown, and the sapwood, which is from 1 to 2 or more inches thick, is nearly white. The pores of the heartwood of white oaks are usually plugged with a froth-like growth known as tyloses, which tend to make the wood impenetrable to liquids. Chestnut oak lacks tyloses in many of its pores.

To distinguish between white oak and red oak, cut the end grain of the wood smoothly with a sharp knife across several growth rings of average width and with a hand lens examine the small pores in the dense summerwood. If the pores in the summerwood are very small, somewhat angular, and so numerous that it would be exceedingly difficult to count them, the wood belongs to the white oak group.

The wood of white oak is heavy, averaging somewhat heavier than that of red oak. The heartwood of white oak is considered to be somewhat more decay resistant than that of red oak.

4.10 Sweetgum

Sweetgum (Liquidambar styraciflua) is frequently called red gum, star-leaved gum, or merely gum. Lumber from sweetgum is usually divided into two classes--sap gum, the light-colored wood

from the sapwood, and red gum, which is cut from the heartwood.

Sweetgum grows from southwestern Connecticut westward into Missouri and southward to the Gulf. Lumber production is almost entirely from the Southern and South Atlantic States.

The wide sapwood of sweetgum is white, tinged with pink. The heartwood is reddish brown. The annual rings are inconspicuous, and the wood is uniform in texture. It has interlocked grain, a form of cross grain, and must be carefully dried. The interlocked grain causes a ribbon stripe. Sweetgum is rated as moderately heavy and hard. It is moderately strong, moderately stiff, and moderately high in shock resistance. Sweetgum is classed with wood of intermediate decay resistance.

4.11 Sycamore, American

American sycamore (Platanus occidentalis) is also known as sycamore, and sometimes as button-wood, button-ball tree, and plane-tree. Sycamore grows from Maine to Nebraska, Texas, and northern Florida. In the production of sycamore lumber, the Central States rank first, followed by the Southern States and the South Atlantic States.

The heartwood of sycamore is reddish brown; sapwood is lighter in color and from 1-1/2 to 3 inches thick. In quarter-sawed lumber, the rays are very conspicuous and, though smaller, resemble those in quarter-sawed oak. The wood has a fine texture and interlocked grain. It shrinks moderately in drying and requires careful seasoning. Sycamore wood is moderately heavy, moderately hard, moderately stiff, moderately strong, and has good resistance to shock.

4.12 Tupelo

The tupelo group includes water tupelo (Nyssa aquatica), also known as tupelo gum, swamp tupelo, and gum; black tupelo (Nyssa sylvatica), also known as blackgum, and sour gum; swamp tupelo (Nyssa sylvatica var. bilfora), also known as swamp blackgum, blackgum, tupelo gum, and sour gum; and ogeechee tupelo (Nyssa ogeche), also known as sour tupelo, gopher plum, tupelo, and ogeechee plum.

All except black tupelo grow principally in the southeastern United States. Black tupelo grows in the eastern United States from Maine

to Texas and Missouri. About two-thirds of the production of tupelo lumber is from the Southern States and nearly another one-third from the South Atlantic States. The small amount from the Middle Atlantic and Central States is largely black tupelo.

Wood of the different tupelos is quite similar in appearance and properties. Heartwood is light brownish gray and merges gradually into the lighter-colored sapwood, which is generally several inches wide. Annual rings are indistinct and frequently very difficult to count. The wood has fine uniform texture and interlocked grain, which prevents splintering and makes the wood difficult to split. Tupelo wood is rated as moderately heavy. It is moderately strong, moderately hard and stiff, and moderately high in shock resistance. Because of interlocked grain, tupelo lumber requires care in drying.

Softwood Pallet Species

4.13 Baldcypress

Baldcypress (*Taxodium distichum*) is commonly known as cypress, also as southern cypress, red cypress, yellow cypress, and white cypress. Commercially, the terms "tidewater red cypress," "gulf cypress," "red cypress (coast type)," and "yellow cypress (inland type)" are frequently used.

Cypress grows along the Atlantic Coastal Plain from Delaware to Florida, westward through the Gulf Coast region to the Mexican border in Texas, and up the Mississippi Valley to southern Indiana. About one-half of the cypress lumber production comes from the Southern States and one-fourth from the South Atlantic States.

Sapwood of cypress is narrow and nearly white. The color of the heartwood varies widely, ranging from light yellowish brown to dark brownish red, brown, or chocolate. The wood of cypress is moderately heavy, moderately strong, and moderately hard, and its heartwood is one of our most decay-resistant woods. Shrinkage is moderately small, somewhat greater than that of cedar, but less than that of southern yellow pine.

Frequently the wood of certain cypress trees contains pockets or localized areas that have been attacked by a fungus. Such wood is known as "pecky" cypress. The decay caused by this fungus

is arrested when the wood is cut into lumber and dried. Pecky cypress therefore is durable and useful where appearance is not important and watertightness is unnecessary.

4.14 Douglas-fir

Douglas-fir (Pseudotsuga taxifolia) is also known locally as red fir, Douglas spruce, yellow fir, and Oregon pine.

The range of Douglas-fir extends from the Rocky Mountains to the Pacific Coast and from Mexico to central British Columbia. Most of the Douglas-fir production comes from the coast States of Oregon, Washington, and California, principally Oregon, and some from Idaho and Montana.

Sapwood of Douglas-fir is narrow in old-growth trees but may be as much as 3 inches wide in second-growth trees of commercial size. Fairly young trees of moderate to rapid growth have reddish heartwood and are called red fir. Very narrow-ringed wood of old trees may be yellowish brown in color and is known on the market as yellow fir.

The wood of Douglas-fir varies widely in weight and strength. The heaviest wood of Douglas-fir frequently has from 12 to 16 growth rings per inch. Douglas-fir wood splits easily. It is intermediate in decay resistance.

4.15 Firs, true

Eight commercial species make up the group of true firs: Balsam fir (Abies balsamea), California red fir (Abies magnifica), Fraser fir (Abies fraseri), grand fir (Abies grandis), noble fir (Abies procera), Pacific silver fir (Abies amabilis), subalpine fir (Abies lasiocarpa), and white fir (Abies concolor). Of these, all but balsam and Fraser fir are often marketed together as commercial white fir. Balsam fir and Fraser fir grow in the east, the other six in the west.

In the United States, balsam fir grows principally in New England, New York, Pennsylvania, and the Lake States. Fraser fir grows in the Appalachian Mountains of Virginia, North Carolina, and Tennessee. White fir grows from the Rocky Mountains to the Pacific Coast. Subalpine fir grows at high altitudes in the Rocky Mountain region and the Cascade Mountains of Oregon and Washington. Pacific silver fir is found in Oregon and Washington.

Grand fir's range is western Montana, northern Idaho, northeastern Oregon, and along the coast from Washington to northern California. Noble fir grows in the mountains of northwestern Washington, western Oregon, and northern California. California red fir is limited to the mountains of southwestern Oregon and northern and eastern California. The western true firs (commercial white fir) are cut for lumber primarily in Oregon and Washington. The rest comes from California and Rocky Mountain areas.

The wood of the true firs is creamy white to pale brown. Heartwood and sapwood are generally indistinguishable. Because of their similarity of structure, wood of the true firs cannot be separated from an examination of the wood alone. Balsam fir is rated as light in weight, low in bending and compressive strength, moderately limber, soft, and low in resistance to shock. The western firs, except grand fir, have somewhat higher strength properties than balsam fir. Shrinkage of the wood is rated from small to moderately large; noble fir and California red fir shrink most. The wood of the true firs is low in decay resistance.

4.16 Hemlock, Eastern

Eastern hemlock (*Tsuga canadensis*) grows from New England southward along the Appalachian Mountains to northern Alabama and Georgia, and in the Lake States. Other names are Canadian hemlock and hemlock spruce.

The production of hemlock lumber is divided fairly evenly between the New England States, the Middle Atlantic States, and the Lake States. North Carolina, South Carolina, and Virginia also produce considerable amounts.

The heartwood of eastern hemlock is pale brown with a reddish hue. Sapwood is not distinctly separated from the heartwood, but may be lighter in color. Growth rings are distinct. The wood is coarse and uneven in texture and inclined to splinter; old trees tend to have considerable shake. The wood is low in decay resistance. It is moderately light in weight, moderately hard, moderately weak, moderately limber, and moderately low in shock-resisting ability. It requires care in seasoning.

4.17 Hemlock, Western

Western hemlock (Tsuga heterophylla) is also known by several other names, including west coast hemlock, hemlock spruce, western hemlock spruce, western hemlock fir, Prince Albert fir, gray fir, silver fir, and Alaska pine.

The heartwood and sapwood of western hemlock are almost white with a purplish tinge. Sapwood, which is sometimes lighter in color, is generally not over 1 inch thick. Growth rings are distinct. The wood contains small, sound, black knots that are usually tight and stay in place. Dark streaks often found in the lumber are caused by hemlock bark maggots.

Western hemlock is moderately light in weight and moderately low in strength. It is moderately hard, moderately stiff, and moderately low in shock resistance. The wood is not highly resistant to decay. It has moderately large shrinkage, about the same as Douglas-fir. Green hemlock lumber contains considerably more water than Douglas-fir, but it is comparatively easy to kiln dry.

4.18 Larch, Western

Western larch (Larix occidentalis) grows in western Montana, northern Idaho, northeastern Oregon, and on the eastern slope of the Cascade Mountains in Washington. It is found at elevations of 2,000 to 7,000 feet. About two-thirds of the lumber of this species is produced in Idaho and Montana and one-third in Oregon and Washington.

The heartwood of western larch is yellowish brown and the sapwood yellowish white. Sapwood is generally not more than 1 inch thick. Growth rings are distinct; they are generally quite uniform and range from 15 to 30 per radial inch. The wood is moderately strong, stiff, moderately hard, moderately high in shock resistance, and moderately heavy. It has moderately large shrinkage. The wood is usually straight-grained, splits easily, and is subject to ring shake. It has about the same decay resistance as Douglas-fir. Knots are common but small and tight. If proper drying schedules are used, western larch can be seasoned satisfactorily.

4.19 Pine, Eastern White

Eastern white pine (Pinus strobus) grows in the United States from Maine southward along the Appalachian Mountains to northern Georgia and Alabama, and in the Lake States. It is also known as white pine, northern white pine, Weymouth pine, and soft pine.

Lumber production of eastern white pine is confined principally to the New England States, which produce about one-half of the total. About one-third comes from the Lake States and most of the remainder from the Middle Atlantic and South Atlantic States.

The heartwood of eastern white pine is light brown, often with a reddish tinge. It turns considerably darker on exposure. Growth rings are distinct. The wood has comparatively uniform texture, and is straight-grained. It is easily kiln dried, has small shrinkage, and ranks high in ability to stay in place. It is also easy to work and can be readily glued. Eastern white pine is light in weight, moderately soft, moderately weak, and low in resistance to shock. The heartwood is rated as intermediate in decay resistance.

4.20 Pine, Lodgepole

Lodgepole pine (Pinus contorta) grows in the Rocky Mountain and Pacific Coast regions and is cut largely in the Central Rocky Mountain States.

The heartwood of lodgepole pine varies from light yellow to light yellow-brown. The sapwood is yellow or nearly white. The wood is generally straight-grained with narrow growth rings.

The wood is moderately light in weight, fairly easy to work, and has moderately large shrinkage. In strength properties, lodgepole pine rates as moderately weak, moderately stiff, moderately soft, and moderately low in shock resistance. It is low in decay resistance.

4.21 Pine, Ponderosa

Ponderosa pine (Pinus ponderosa) grows in every state west of the Great Plains; major producing areas are in California, Oregon, Washington, Idaho, and Montana.

Although ponderosa pine belongs to the yellow pine group, much of its wood is similar in appearance and properties to that of the white pines. Heartwood is light reddish brown, and the wide sapwood is nearly white to pale yellow. Growth rings are generally distinct when not exceedingly narrow.

The wood of the outer portions of ponderosa pine of saw-timber size is generally moderately light in weight. It is moderately low in strength, moderately stiff, moderately soft, and moderately low in shock resistance. It is generally straight-grained and has moderately small shrinkage. It is quite uniform in texture and has little tendency to warp and twist. Wood in young trees and in the heartwood of older trees is sometimes heavier, harder, and stronger than that in the outer portion of the older trees.

4.22 Pine, Red

Red pine (*Pinus resinosa*) is frequently called Norway pine. It is occasionally known as hard pine and pitch pine. Red pine grows in the New England States, New York, Pennsylvania, and the Lake States. In the past, lumber from red pine has been marketed with white pine without distinction as to species.

The heartwood of red pine varies in color from pale red to a reddish brown. The sapwood is nearly white with a yellowish tinge and is generally from 2 to 4 inches wide. The wood resembles the lighter-weight wood of southern yellow pine. Summerwood is distinct in the growth rings. Red pine is moderately heavy, moderately strong and stiff, moderately soft, and moderately high in shock resistance. It is generally straight-grained, not so uniform in texture as eastern white pine, and somewhat resinous. The wood has moderately large shrinkage, but is not difficult to dry and stays in place well when seasoned. It is low in decay resistance.

4.23 Pine, Southern Yellow

There are a number of species included in the group marketed as southern yellow pine lumber. The most important and their growth ranges are:

(1) Longleaf pine (*Pinus palustris*), which grows from eastern North Carolina south into Florida, and westward into eastern Texas.

(2) Shortleaf pine (Pinus echinata), which grows from southeastern New York and New Jersey southward to northern Florida and westward into eastern Texas and Oklahoma. Northern limits of growth are the Ohio Valley and southern Missouri.

(3) Loblolly pine (Pinus taeda), which grows from Maryland southward through the Atlantic Coastal Plain and Piedmont Plateau into Florida and westward into eastern Texas. The northern limit of growth west of the Appalachian Mountains is near the southern Tennessee border.

(4) Slash pine (Pinus eliottii), which grows in Florida and the southern parts of South Carolina, Georgia, Alabama, Mississippi, and Louisiana east of the Mississippi River.

Other southern yellow pines of less commercial importance include Virginia pine (Pinus virginiana), pond pine (Pinus rigida serotina), and spruce pine (Pinus glabra).

Many names are applied to the lumber and trees of the various species of southern yellow pine. Longleaf is known also as pitch pine in export trade and as Georgia pine, Florida pine, Texas yellow pine, and hard pine. Slash pine may be called Cuban pine, yellow slash pine, swamp pine, and pitch pine. Shortleaf pine may be called yellow pine, Arkansas shortleaf pine, North Carolina pine, and Rosemary pine. Loblolly pine is known as oldfield pine, North Carolina pine, sap pine, and shortleaf pine.

Southern yellow pine lumber comes principally from the Southern and South Atlantic States. States that lead in production are Georgia, Alabama, North Carolina, and Texas.

The wood of the various southern yellow pines is quite similar in appearance. The sapwood is yellowish white (usually white in second-growth stands), and the heartwood is reddish brown. Heartwood begins to form when the tree is about 20 years old. In old, slow-growth trees, sapwood may be only 1 or 2 inches in width. Growth rings in the southern yellow pines are usually prominent, each made up of a band of dark-colored summerwood and a band of light-colored springwood. Width of the annual rings varies greatly, depending upon the conditions under which the trees have grown. Rings may be as much as 1 inch in width in young trees in old-field stands or extremely narrow in the outer part of old-growth trees.

Longleaf and slash pines are classed as heavy, strong, stiff, hard, and moderately high in shock resistance. Shortleaf and loblolly pine are usually somewhat lighter in weight than longleaf. The other less important species of southern yellow pine have properties similar to shortleaf and loblolly pine.

In order to obtain heavy, strong wood of the southern yellow pines for structural purposes, a "density rule" has been written that specifies certain visual characteristics for structural timbers.

Heartwood of the southern yellow pines is intermediate in decay resistance. The sapwood can be readily treated with preservatives to improve its decay resistance. Southern yellow pine lumber can be satisfactorily seasoned either by air drying or by kiln drying. All the southern yellow pines have moderately large shrinkage but stay in place well when properly seasoned.

4.24 Pine, Sugar

Most of the lumber from sugar pine (Pinus lambertiana) is produced in California and the remainder in southwestern Oregon.

The heartwood of sugar pine is buff or light brown, sometimes tinged with red. Sapwood is creamy white. Sugar pine contains resin canals, which show on cross sections or tangential faces as small, dark-colored dots or as thin, dark-colored streaks. During seasoning the wood frequently becomes discolored because of the action of blue stain fungi or a chemical reaction resulting in brown stain. These stains do not affect the strength properties of the wood but do affect its appearance. The wood is straight-grained, fairly uniform in texture, and easy to work with tools. It has very small shrinkage, is readily seasoned without warping or checking, and stays in place well. Sugar pine is light in weight, moderately weak, moderately soft, low in shock resistance, and low in stiffness. It is rated as intermediate in decay resistance.

4.25 Spruce, Eastern

The term "eastern spruce" includes three species, red (Picea rubens), white (Picea glauca), and black spruce (Picea mariana). White spruce and black spruce grow principally in the Lake States and New England, and red spruce in New England and the Appalachian Mountains. All three species have about the same properties, and in commerce no distinction is made between

them. The wood dries easily, stays in place well, is moderately light in weight and easily worked, has moderate shrinkage, and is moderately strong, stiff, tough, and hard. The wood is light in color, and there is little difference between the heartwood and softwood.

4.26 Spruce, Engelmann

Engelmann spruce (Picea engelmannii) grows at high elevations in the Rocky Mountain regions of the United States. About two-thirds of the lumber is produced in the southern Rocky Mountain States. Most of the remainder comes from the northern Rocky Mountain States and Oregon.

The heartwood of Engelmann spruce is nearly white with a slight tinge of red. The sapwood varies from 3/4 inch to 2 inches in width and is often difficult to distinguish from heartwood. The wood has medium to fine texture and is generally straight-grained. Engelmann spruce is rated as light in weight and has low strength as a beam or post. It is limber, soft, low in shock resistance, and has moderately small shrinkage. The lumber contains small knots.

4.27 Spruce, Sitka

Sitka spruce (Picea sitchensis) is a tree of large size growing along the northwestern coast of North America from California to Alaska. About two-thirds of the production of Sitka spruce lumber comes from Washington and one-third from Oregon. Small amounts are produced in California.

The heartwood of Sitka spruce is a light pinkish brown. Sapwood is creamy white and shades gradually into the heartwood. Sapwood may be 3 to 6 inches wide or even wider in young trees. The wood has a comparatively fine, uniform texture, and is generally straight-grained. It is moderately light in weight, moderately low in bending and compressive strength, moderately stiff, moderately soft, and moderately low in resistance to shock. It has moderately small shrinkage. On the basis of weight, it rates high in strength properties, and can be obtained in clear, straight-grained pieces of large size.

SECTION V

5. Moisture Relations in Wood

5.1 Moisture Content of Green Wood

In living trees, the sapwood generally contains more water than the heartwood. This is particularly true of the softwoods, in which there is often considerably more water in the sapwood than in the heartwood. On the other hand, in many of the hardwoods the moisture content of heartwood and sapwood is more uniform.

The sapwood of living trees often contains more than 100 percent of moisture, and trees have been found in which the moisture content was over 300 percent of the dry weight. In such cases the cell walls are fully saturated, and the cell cavities are almost filled with water. In the heartwood of some green softwoods, the moisture content is as low as 30 percent.

5.2 Relation of Moisture Content of Wood, Relative Humidity, and Temperature

When wood is exposed to a constant temperature and relative humidity, it will in time come to a definite moisture content that balances the amount of moisture in the surrounding air. This moisture content is called the equilibrium moisture content. The relationship between the moisture content of wood and the surrounding atmospheric conditions is shown in Fig. 61. Under constant temperature conditions the moisture content increases as the relative humidity increases; under constant relative humidity conditions the moisture content decreases as the temperature increases.

In general, the relative humidity of the atmosphere is lower in the spring and summer than during the autumn and winter, and seasoned wood exposed to these changes in relative humidity will absorb or lose moisture accordingly in order to reach an equilibrium moisture content.

Relative humidity also varies in different parts of the country as affected by altitude, proximity to the ocean, precipitation, or

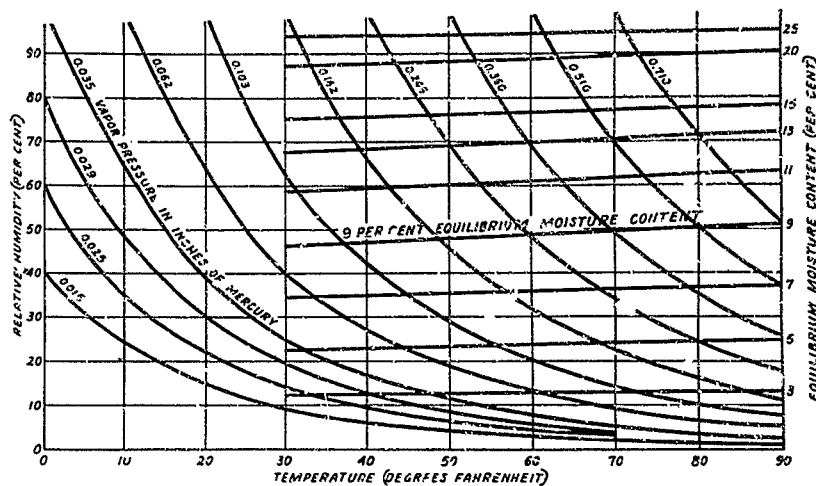
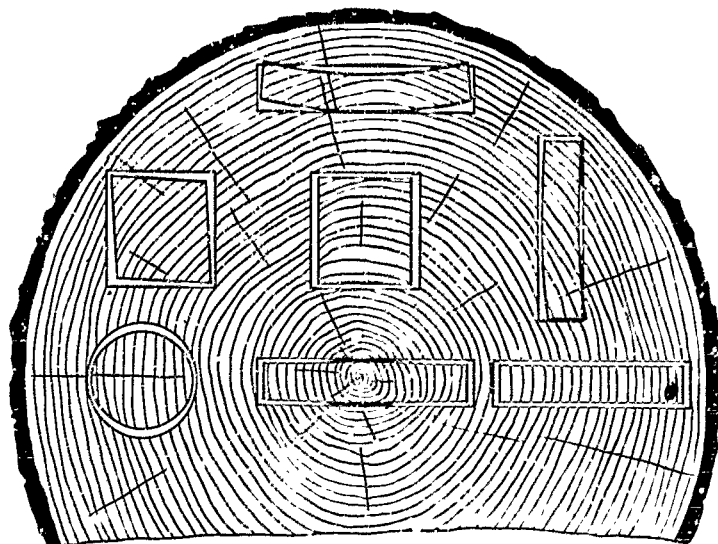


Fig. 61. - Relationship of relative humidity, vapor pressure, equilibrium moisture content, and temperature. (ZM17222F)

Fig. 62. - Effects of radial and tangential shrinkage on the shape of various sections in drying from the green condition. (ZM12494F)



other local conditions. Table 2 shows the average relative humidity for a number of widely separated cities in the United States at different times of the year. Similar seasonal variations occur in other parts of the world. In tropical and subtropical areas, where long rainy seasons are followed by long dry spells, the spread of equilibrium moisture content between seasons may be considerable. Low equilibrium moisture content conditions may be expected in desert areas. In Europe generally the average equilibrium moisture content would be as high as, or higher than, that along the northeastern coast of the United States.

The approximate equilibrium moisture content for wood can be estimated for any section of the country and for any season by noting the relative humidity given in table 2 and reading the corresponding moisture content from Fig. 61 at the particular temperature under consideration. Moisture content variations in wood in service can be minimized by fabricating or installing the wood at a moisture content corresponding to the average atmosphere conditions to which it will be exposed.

5.3 Shrinkage of Wood

Wood shrinks as it loses moisture and swells as it absorbs moisture.

Wood from the tree may contain from 30 to 250 percent of water, based on the weight of the oven-dry wood. This water is held in the wood in two ways--imbibed water in the walls of the wood cells and free water in the cell cavities. When wood begins to dry, the free water leaves first, followed by the imbibed water. The fiber-saturation point is that condition in which all the free water has been removed but all the imbibed water remains; for most species this point is approximately 30 percent moisture content.

Wood shrinks only if its moisture content is reduced below the fiber-saturation point. In seasoning green wood, however, the surface dries more rapidly than the interior and reaches the fiber-saturation point first; shrinkage may therefore start while the average moisture content is considerably above the fiber-saturation point. Wood shrinks most in the direction of the annual growth rings (tangentially), about one-half to two-thirds as much across these rings (radially), and very little, as a rule, along the grain (longitudinally). The combined effects of radial and tangential shrinkage on the shape of various sections in drying from

the green condition are illustrated in Fig. 62. Greater shortening occurs in a cross-grained board than would occur in a straight-grained piece.

Shrinkage is usually expressed as a percentage of the green dimensions, which represent the natural size of the piece. Table 4 gives the range in shrinkage in different directions for most of the commercially important native species.

Shrinkage in drying is proportional to the moisture lost below the fiber-saturation point. Approximately one-half the total shrinkage possible has occurred in wood seasoned to an air-dry condition (12 to 15 percent moisture content) and about three-fourths in lumber kiln dried to a moisture content of about 7 percent. Hence, if wood is properly seasoned, manufactured, and installed at a moisture content in accord with its service conditions, there is every prospect of satisfactory performance without serious changes in size or distortion.

In general, the heavier species of wood shrink more across the grain than the lighter ones. Heavier pieces also shrink more than lighter pieces of the same species. When shrinkage is more of a factor than hardness or strength, a lightweight species should be chosen. When both hardness or strength and low shrinkage are very important, then an exceptional species, such as black locust, should be chosen.

5.4 Moisture Content of Seasoned Lumber

The trade terms "green," "shipping dry," "air dry," and "kiln dried," although widely used, have no specific or agreed meaning with respect to moisture content except in a few instances where lumber association rules define moisture content limits for kiln-dried and air-dried lumber. The wide limitations of these terms as ordinarily used are covered in the following statements, which, however, are not to be construed as exact definitions:

"Green lumber"--lumber that may be freshly cut or partially seasoned but which has not yet reached a shipping-dry or air-dry condition. The term may also be applied to lumber that has a higher moisture content than is acceptable for manufacture into finished products.

"Shipping-dry lumber"--lumber that has been partially dried, either in a kiln or by air drying, to reduce weight and freight

charges, and which may have a moisture content of 30 percent or more.

"Air-dry lumber"--lumber that has been exposed to the air for any length of time. If exposed for a sufficient time, it may have a moisture content ranging from 6 percent, as in summer in the arid Southwest, to 24 percent, as in winter in the Pacific Northwest. For the United States as a whole, the minimum moisture content range for thoroughly air-dry lumber is 12 to 15 percent in the summer, and the average is somewhat higher. Sometimes such terms as "90 days on sticks" or "4 months in the yard" are used instead of "air-dry" to denote the length of time the lumber remained in the yard piles. Since lumber seasons slowly in cold weather, less drying would take place during the winter than during the summer, and a given period in the yard would not mean the same degree of seasoning in cold or wet months as would occur in summer or dry months (table 3).

"Kiln-dried lumber"--lumber that has been kiln dried for any length of time. The term applies to lumber dried to "shipping dry," as defined previously, as well as to stock dried to a final moisture content of 8 to 12 percent. Specifications covering kiln-dried lumber intended for immediate processing into a finished product should state the average moisture content, tolerance of individual pieces above and below the average, and moisture distribution between surface and center.

5.5 Moisture Content Determination

Two methods of determining the moisture content of wood are recognized: (1) Drying of a sample in an oven, and (2) using an electric moisture meter. They are not interchangeable but complement one another, since each has a distinct field of usefulness not covered by the other. Since the moisture content will vary between pieces in a given log or shipment, with either method a number of tests must be made to obtain an average. Intelligent selection of test pieces and a suitable number of samples to represent the total lot will minimize error.

5.6 Oven-dry method.--The moisture content of a test section of wood can be determined accurately by the oven-dry method, regardless of original moisture content, moisture distribution, size, species, density, or temperature of the wood being tested. On the other hand, this method necessitates cutting into and wasting part of the original board or plank and requires 24 hours

or more. The moisture content of wood is determined by the oven-dry method as follows:

(1) Select a representative sample. A good sample from a pallet board is a cross section 1 inch long, taken about 1 foot from the end of the board.

(2) Immediately after sawing the sample, remove all loose splinters from it and accurately weigh it.

(3) Put the sample in an oven maintained at a temperature of 212° to 221° F. (100° to 105° C.) and dry until constant weight is attained.

(4) Reweigh the sample to obtain the oven-dry weight.

(5) Divide the loss in weight by the oven-dry weight and multiply the result by 100 to get the percentage of moisture in the original sample. Thus,

$$\text{Percentage of moisture} = \frac{(W - D)}{D} \times 100$$

where W is the original weight as found under (2), and D is the oven-dry weight as found under (4).

5.7 Electric moisture meters.--Electric moisture meters give an instantaneous moisture content reading, based on the effect of moisture on the electrical resistance or capacity of wood. The values are affected by a number of factors, such as density, species, temperature, moisture distribution, and thickness of material. The presence of glue or paint may affect the accuracy. Many moisture meters are limited to readings covering a moisture-content range between 7 and 25 percent.

Moisture meters will not satisfactorily serve in place of kiln samples used in dry kilns for the guidance of kiln operators. These instruments are of value, however, for the control of moisture content of lumber being processed, or purchased under moisture content specifications, since they give instantaneous readings and are sufficiently accurate for this purpose. Since such lumber is generally of a single species, the necessary corrections can be made for species and for temperature. Occasionally, check readings should be made on lumber of the same shipment and species, preferably on the same test section, whose moisture content has been determined by the oven-dry method.

The moisture-meter readings may not always agree absolutely with the oven-dry determination, but when significant differences occur, the results of the oven-dry tests should take precedence over the meter readings.

The electrical-resistance type of meter generally has a range of measurement of 7 to 25 percent moisture content, although some meters have special scales extending to about 60 percent. Measurements made within the higher range are not, however, so accurate as those made at from 7 to 25 percent. Most measurements needed are between 7 and 25 percent, and the higher range is used only in special instances.

Measurements of electrical resistance with a portable meter are very difficult to make at moisture content values below 7 percent because of the high electrical resistance of dry wood.

Instruments that measure the electrical capacity of wood may also be used for determining variations in moisture content. In this instance, a high-frequency electric field is created by the instrument adjacent to the electrode. Materials introduced into this electrical field absorb energy and affect the flow of current in the circuit. This change is shown by a meter that may be calibrated for a single species or have an arbitrary scale that can be converted into moisture content readings from tables supplied by the manufacturer. Variations in the density of the wood affect the accuracy of the capacity-type instrument, so that the instrument should not be used indiscriminately on species for which it is not calibrated.

The following conditions should be observed in making moisture content tests electrically:

- (1) Follow the written instructions of the manufacturer of the moisture meter.
- (2) Apply corrections for species, temperature, or density when necessary.
- (3) Make measurements at several points on the faces of the boards.
- (4) Do not make measurements on the end of lumber.

(5) Do not assume moisture content values when calibrations have not been made.

(6) Drive needle points full depth and with the current flow parallel to the grain.

(7) Do not use plate electrodes, such as on capacity-type meters, on rough lumber.

(8) Do not make measurements on lumber that has been subjected to surface wetting, such as rain or fog.

(9) Avoid measurements above 100° F. or below 30° F., which are not recommended because satisfactory temperature-correction data is not available.

(10) If the needle points cause splitting of veneers, disregard the readings.

(11) Regard moisture content measurements with needle electrodes on plywood as approximate, since glue lines containing electrolytes are likely to show moisture-content values that are too high.

(12) If moisture meters are to be used on lumber thicker than 1 inch, drive the contact points to a depth equal to one-fifth of the lumber thickness.

(13) If a moisture meter does not function properly, return it to the manufacturer for recalibration.

SECTION VI

6. Limitation of Defects in Pallet Lumber

6.1 Knots

A knot is the base of a limb embedded in the tree trunk. Normally a knot starts at the pith and increases in diameter from the pith outward as long as the limb is alive.

When the limb is alive, its fibers interlace with those of the tree trunk, producing an intergrown knot (Fig. 63). Many of the lower limbs die after a time, however, as a result of shading or other causes, but they may not break off for many years thereafter. After the death of a limb, the wood formed in the tree trunk makes no further connection with it but grows around it, producing an encased knot, which may be either loose, so that it will drop out, or tight, so that it is held in position when the trunk is sawed into lumber (Fig. 64). When lumber dries, the knots shrink more than the surrounding wood and may check or loosen. Eventually, the dead limb breaks off, the stub heals over, and the distortion of grain in successive growth layers becomes less and less with increasing diameter of the trunk, until finally clear wood with normal grain is produced in the area covering the knot.

When a knot is cut through transversely, a round knot results, when cut obliquely an oval knot results, when cut lengthwise a spike knot results (Figs. 63 and 64). A sound, tight knot is solid across its face, fully as hard as the surrounding wood, shows no signs of decay, and is so fixed by growth or position that it will firmly retain its place in the piece.

Knots are objectionable on account of the distortion and, in encased knots, the discontinuity of the grain that they produce, thereby weakening the wood, causing irregular shrinkage, and making machining more difficult. Loose knots are likely to drop out. In resinous species pitch often exudes more freely from knots than from the clear wood, and in all species knots usually are considered as marring the appearance of the lumber unless painted.

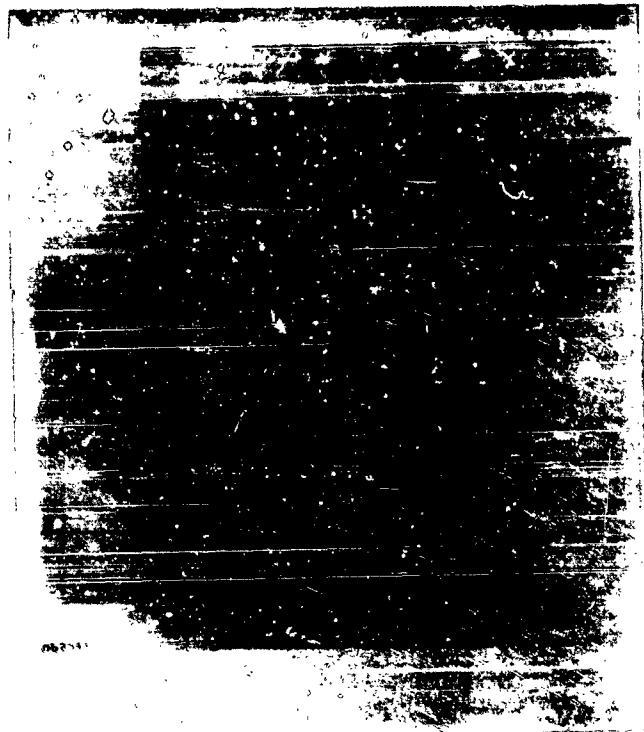


Fig. 63. - Intergrown round knots in yellow pine.
(M6894F)

Fig. 64. - Left: An encased knot in hemlock. Right: A spike knot intergrown for most of its length in southern yellow pine. (M6893F)



Knots in pallet lumber are limited by their average diameter, as shown in Fig. 65.

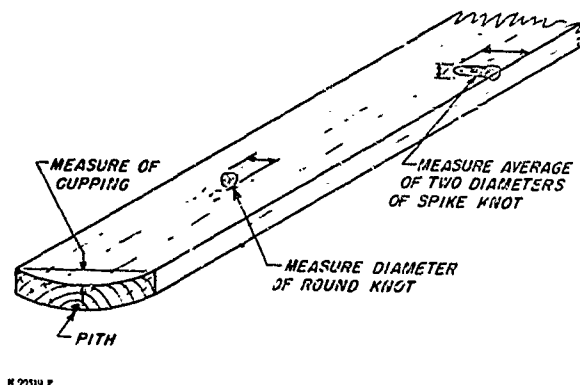


Fig. 65. - Board showing pith and methods of measuring cup and measuring round or spike knots. (M90319F)

6.2 Checks, Splits, and Shakes

A check is a longitudinal crack in wood, generally in the radial direction, or across the annual rings (Fig. 66). Checks usually result from shrinkage in seasoning. Thick lumber checks more severely than thin lumber. A split is a longitudinal crack that extends through the full thickness of a board. It often takes a radial direction and may be called a through check. Checks or splits in pallet lumber may be limited in length, which is measured as indicated in Fig. 66.

A shake is a longitudinal crack in wood between two annual rings (Fig. 66). Shakes originate in green timber but may be extended in seasoning. They indicate a weakness of bond between annual rings that extends lengthwise beyond the visible opening. For this reason shakes in pallet lumber should be limited by width as well as length (Fig. 66).

Figure 67 shows photographic views of checks and shakes in boards.

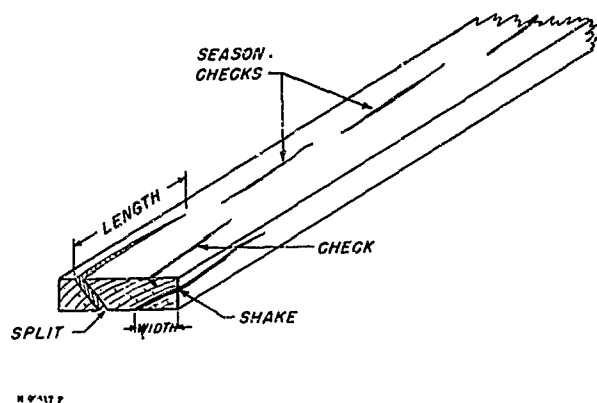
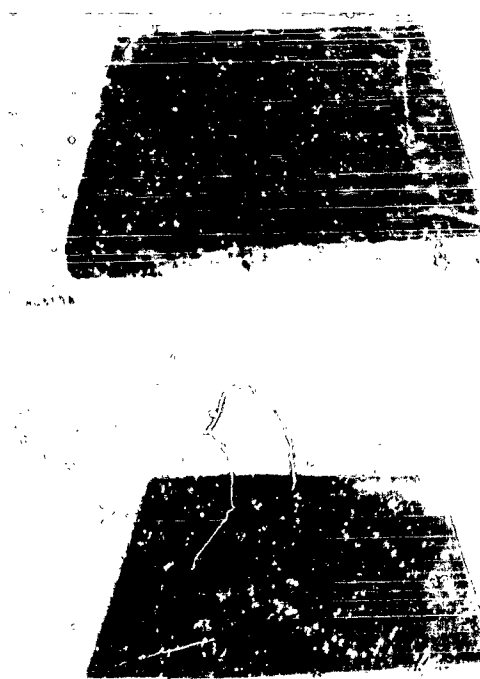


Fig. 66, - Board showing shake, split, and season checks. (M90317F)

Fig. 67. - Above: Checks in a flat-grained board. (M6889F)

Below: Shake in a flat-grained board. (M6890F)



6.3 Cross Grain

In cross-grained wood the fibers are not parallel to the length of the board. The principal types of cross grain are diagonal grain and spiral grain.

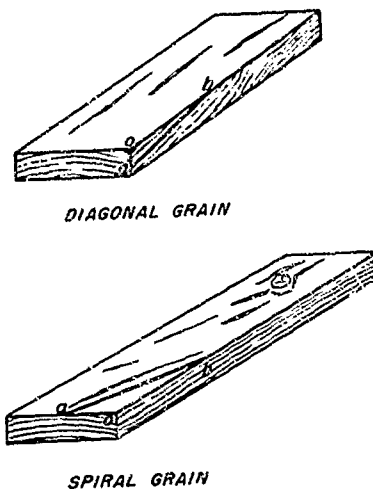
Diagonal grain results from sawing a board at an angle other than parallel with the bark. It is easily detected by noting the slope of the annual rings on an edge-grain or radial surface.

Spiral grain is caused by the fibers growing spirally around the trunk of a tree instead of in a vertical course (Fig. 68). In lumber it is not always apparent to the eye, but can often be detected by the direction of surface checks on a flat-grained (tangential) surface (Fig. 67). The direction followed by a split in the radial plane will show the slope of spiral grain.



Fig. 68. - Spiral-grained and straight-grained forest trees.
(M6918F)

Cross grain is usually measured as the number of inches of length in which a deviation of 1 inch from parallel occurs (Fig. 69). Small local deviations, as around knots, are disregarded. Cross grain is not usually a serious defect in pallet lumber, but boards with slope of grain steeper than 1 in 5 are greatly weakened and are likely not to stay in place well with seasoning.



SLOPE OF GRAIN IS EXPRESSED AS THE RATIO $oa:ob$.
 SMALL LOCAL DEVIATIONS ARE USUALLY DISREGARDED
 IN DETERMINING THE GRAIN DIRECTION ob .

Fig. 69. - Measurement of diagonal grain and spiral grain.
 (M92180F)

6.4 Pockets and Streaks

Pitch pockets are lens-shaped openings within annual rings, usually longer than they are wide. As a rule, they contain more or less free resin and, occasionally, bark. They may be from less than an inch to several inches in length. Pitch pockets normally occur only in certain conifers, namely, pine, Douglas-fir, spruce, tamarack, and larch. They are most common in southern yellow pine and Douglas-fir and least common in redwood. They are objectionable because they may weaken small members and resin may exude from them, especially when the wood becomes warm. Figure 70 shows how a pitch pocket may appear in the end and on the flat surface of a board.

A bark pocket is a patch of bark partially or wholly enclosed in the wood. There is usually some slight separation, or at least a lack of cohesion, involved that has a definite weakening effect. In appearance, bark pockets resemble pitch pockets more closely than any other defect but they are usually smaller and do not contain resin.

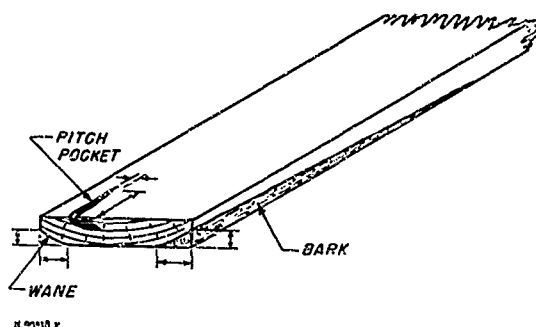


Fig. 70. - Board with pitch pocket, wane, and bark. (M90318F)

Pitch streaks are well-defined infiltrations of resin in the fibers in the form of streaks, usually extending a greater distance along than across the grain (Fig. 71). They normally occur only in pine, Douglas-fir, spruce, tamarack, and larch.

Mineral streaks are dark brown or black streaks, frequently with a green tinge, and often contain mineral matter in sufficient quantities to dull sharp-edged tools. They vary in length from less than an inch to a foot or more along the grain and at their widest portion may extend $1/8$ inch to 1 inch or more across the grain (Fig. 71). Their limits may be sharply defined, or they may fade out gradually into the surrounding wood. Mineral streaks are frequently infected by fungus, and they check more easily in seasoning than normal wood. Mineral streaks are common in maple, hickory, basswood, yellow-poplar, and yellow birch, and are occasionally found in other hardwoods. Evidently they are often, if not always, due to some injury that the living tree received, such as bird pecks, mechanical abrasion, or tapplings for maple sugar. They have little effect on strength or other mechanical properties, and are not considered objectionable in pallet lumber.



Fig. 71. - Above: Pitch streak. Below: Mineral streak.
(M6895F)

6.5 Stain and Decay

Many stains and all forms of decay or rot are caused by fungi that grow on and in wood. Fungi are primitive plants made up of fine threads invisible to the eye unless massed or matted together. Fruiting bodies of these fungi may appear on the surface of the wood. The fruiting bodies of the staining fungi are always small. Those of decay fungi may be very large, and take such forms as toadstools, conks, and brackets. Since they are not formed until the fungi have developed vigorously inside the wood, their presence indicates serious infection.

Lumber with a moisture content of less than 20 percent will not stain or decay.

The most common stain is the blue stain that occurs in the sapwood of many species of wood and is often known as sap stain. The sapwood is mottled or streaked with a bluish or grayish stain (Fig. 72); in advanced stages the entire sapwood becomes dark blue-gray or

almost black. A stain of this type ordinarily does not have a serious effect on strength and is not considered objectionable in pallet lumber. Its presence, however, indicates exposure to conditions that are also favorable to the development of decay, and stained pieces should be carefully examined for decay.



Fig. 72. - Planed sapwood board of southern yellow pine showing dark streaks and irregular zones of blue stain.
(M48578F)

Incipient decay usually appears as a discoloration, often in rather irregular streaks or elongated areas having a reddish or brownish tinge. The streaks extend lengthwise of a board but are not limited to certain annual rings as is the case with most normal color variations in wood. Decay in this stage has only moderate effects on those properties important in pallet lumber, and minor amounts may be admitted.

More advanced decay or rot results in a distinct brown color, a soft or brittle texture, a dry or "dead" appearance, and pronounced cross-cracking. Some types of decay produce discolorations in the wood known as zone lines. These are very narrow black, orange, or yellow lines of various lengths that tend to run somewhat in the direction of the grain of the wood. They are often most prevalent at or near the border of the most conspicuously

discolored areas. Sometimes they border areas only slightly discolored, but their presence is certain evidence of decay. Figure 73 shows advanced decay in wood and prominent zone lines. In some instances, as with the white pocket in Douglas-fir and other species, many small white specks or pockets appear (Fig. 74).

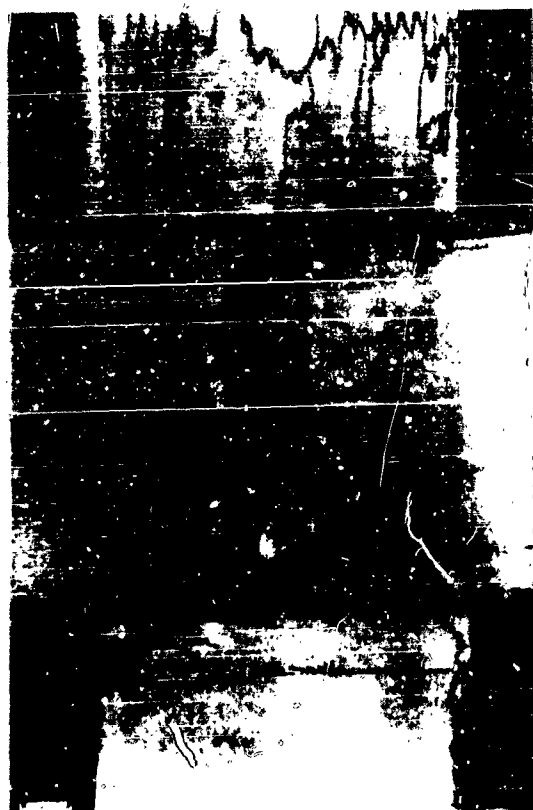


Fig. 73. - Advanced decay in wood, showing prominent zone lines.
(M54327F)

Decay in the advanced stage seriously reduces the strength and toughness of wood and is generally excluded from pallet lumber. Minor amounts of white pocket (Fig. 74) may be allowed where specifications so permit. Small amounts of decay in knots (unsound knots) may be allowed if specifications permit and if the decay does not extend to adjacent areas outside the knot.



Fig. 74. - Pallet boards of Douglas-fir containing white pocket decay in comparatively light degree. (M86765F)

6.6 Manufacturing Defects

Under-size or off-size lumber may result from errors in sawing. Specifications or accompanying drawings for pallets usually indicate permissible limits on size.

Wane is the presence of bark along one or both edges of boards sawed from the outer portion of the tree trunk (Fig. 70). It is limited in terms of the proportion of thickness or width occupied (Fig. 70).

Lumber may be surfaced on one side (S1S), two sides (S2S), one edge (S1E), two edges (S2E), four sides (S4S), or some combination thereof. Some areas, where dimensions are scant, may not surface fully smooth. These areas are known as skips and may be defined and limited by area, depth, or both. A slight skip does not have measurable depth; a shallow skip is one that the planer knife failed to touch by not more than 1/32 inch and a deep skip,

by not more than $1/16$ inch. The term "hit and miss" describes a series of surfaced areas with skips not more than $1/16$ inch deep between them.

Where areas of irregular grain occur, a part of the wood may be torn out below the general dressed surface. Torn grain up to $1/32$ inch deep is classed as slight, up to $1/16$ inch as medium, and up to $1/8$ inch as heavy. Torn grain may also be limited to a proportional part of the face area of a board.

Lumber may become warped during seasoning or kiln drying. Figure 75 shows the kinds of warp that may occur either separately or in combination. Crook is deviation edgewise from a straight line from end to end of a piece. Bow is deviation flatwise from a straight line from end to end. Cup is a curve in a piece across the grain or width of a piece; its measurement is indicated in Fig. 75 and also in Fig. 65. Slight cup measures up to $1/4$ inch, medium cup up to $3/8$ inch, and deep cup up to $1/2$ inch, based on a board 12 inches wide. Cup in a 6-inch board measures half as much or in like proportion for other widths. Twist is a distortion caused by the turning of the edges of a board so that the four corners of any face are no longer in the same plane. Bow or twist in pallet deck boards can usually be straightened by nailing, but cupped boards may split when the two edges are nailed.

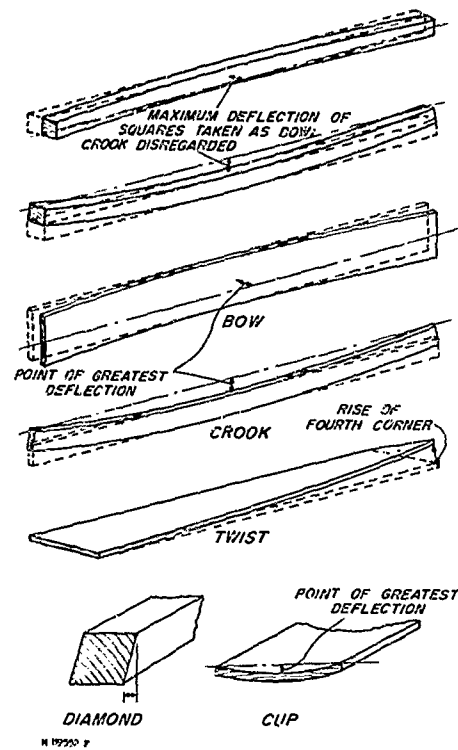


Fig. 75. - Various kinds of warp in boards. (M89552F)

Table 1.--Weights of woods used in pallets

Species	Weight per cubic foot	
	Green	Air-dry (12 percent moisture content)
	Lb.	Lb.
Ash, commercial white ¹	48	41
Baldcypress	51	32
Beech	54	45
Birch ²	57	44
Douglas-fir (coast region)	38	34
Elm, American	54	35
Elm, rock	53	44
Fir, commercial white ³	46	27
Hackberry	50	37
Hemlock, eastern	50	28
Hemlock, western	41	29
Hickory, pecan ⁴	62	45
Hickory, true ⁵	63	51
Larch, western	48	36
Maple, red	50	38
Maple, sugar	56	44
Oak, red ⁶	64	44
Oak, white ⁷	63	47
Pine, eastern (northern) white	36	25
Pine, red (Norway)	42	34
Pine, ponderosa	45	28
Pine, southern yellow:		
Loblolly	53	36
Longleaf	55	41
Shortleaf	52	36
Pine, sugar	52	25

(Sheet 1 of 2)

Table 1.--Weights of woods used in pallets (Cont'd)

	: <u>Lb.</u>	: <u>Lb.</u>
Spruce, eastern ⁸	: 34	: 28
Spruce, Sitka	: 33	: 28
Sweetgum (Red gum)	: 50	: 34
Sycamore	: 52	: 34
Tupelo	: 56	: 35

¹-Average of Biltmore ash, blue ash, green ash, and white ash.

²-Average of sweet birch and yellow birch.

³-Average of grand fir and white fir.

⁴-Average of bitternut hickory, nutmeg hickory, water hickory, and pecan.

⁵-Average of mockernut hickory, pignut hickory, shagbark hickory, and shellbark hickory.

⁶-Average of black oak, laurel oak, northern red oak, pin oak, scarlet oak, southern red oak, swamp red oak, water oak, and willow oak.

⁷-Average of bur oak, chestnut oak, post oak, swamp chestnut oak, swamp white oak, and white oak.

⁸-Average of black spruce, red spruce, and white spruce.

(Sheet 2 of 2)

Table 2. --Relative humidity at different seasons in various parts of the United States¹

City	Mean relative humidity ¹			
	: Winter : Spring : Summer : Autumn			
	: <u>Percent</u> : <u>Percent</u> : <u>Percent</u> : <u>Percent</u>			
New York, N. Y.	: 73	: 70	: 74	: 75
Cleveland, Ohio	: 77	: 72	: 70	: 74
Spokane, Wash.	: 82	: 61	: 47	: 67
Seattle, Wash.	: 83	: 73	: 69	: 81
Phoenix, Ariz.	: 47	: 32	: 32	: 41
San Diego, Calif.	: 74	: 78	: 81	: 78
San Francisco, Calif.	: 79	: 79	: 84	: 80
Denver, Colo.	: 54	: 51	: 49	: 46
Washington, D. C.	: 72	: 69	: 75	: 76
El Paso, Tex.	: 45	: 27	: 41	: 46
Galveston, Tex.	: 84	: 82	: 79	: 78
Jacksonville, Fla.	: 80	: 74	: 80	: 83

¹The relative humidity values given are based on daytime readings made by U.S. Weather Bureau and are not the mean average humidity for 24-hour periods. The relative humidity during the night is usually much higher than during the day, and the equilibrium moisture content will follow the mean average humidity for the 24-hour period.

Table 3. -- Approximate moisture content of thoroughly air-dry 1-inch lumber by months for different regions

Forest Region ¹	Janu- ary	Febru- ary	March	April	May	June	July	August	Septem- ber	Octo- ber	Novem- ber	Decem- ber
California Pine	20	18	16	14	12	10	9	9	10	12	16	18
Redwood	24	25	22	20	18	16	15	15	16	17	19	21
Inland Empire ²	20	20	18	15	14	14	12-1/2	13	14	15	20	20
Oregon and Washington	26	24	22	18	16	15	12	13	15	16	22	26
Southern Pine	20	20	20	13	13	14	14	14	14	15	17	20

¹In the arid Southwest during the driest portion of the year, air-dry lumber dries down to between 5 and 10 percent moisture content.

²Northwestern Montana, Idaho north of the Salmon River, Washington east of the Cascade Mountains, and the Northeastern tip of Oregon.

Table 4. -- Range in average shrinkage of a
number of native species of wood

Direction of shrinkage	: From green to oven-dry condition	: From green to air-dry condition (12 to 15 percent moisture content)
	: <u>Percent of green dimension</u>	: <u>Percent of green dimension</u>
Tangential	: 4.3 - 14.0	: 2.1 - 7.0
Radial	: 2.0 - 8.5	: 1.0 - 4.2
Longitudinal	: .1 - .2	: .05 - .10
Volumetric	: 7.0 - 21.0	: 3.5 - 10.5